SCIENTIFIC AMERICAN SUPPLEMENT No. 854

Scientific American Supplement, Vol. XXXIII. No. 854 | Scientific American, established 1845.

NEW YORK, MAY 14, 1892.

Scientific American Supplement, $5 a year. | Scientific American and Supplement, $7 a year.

A NEW CARGO STEAMER.

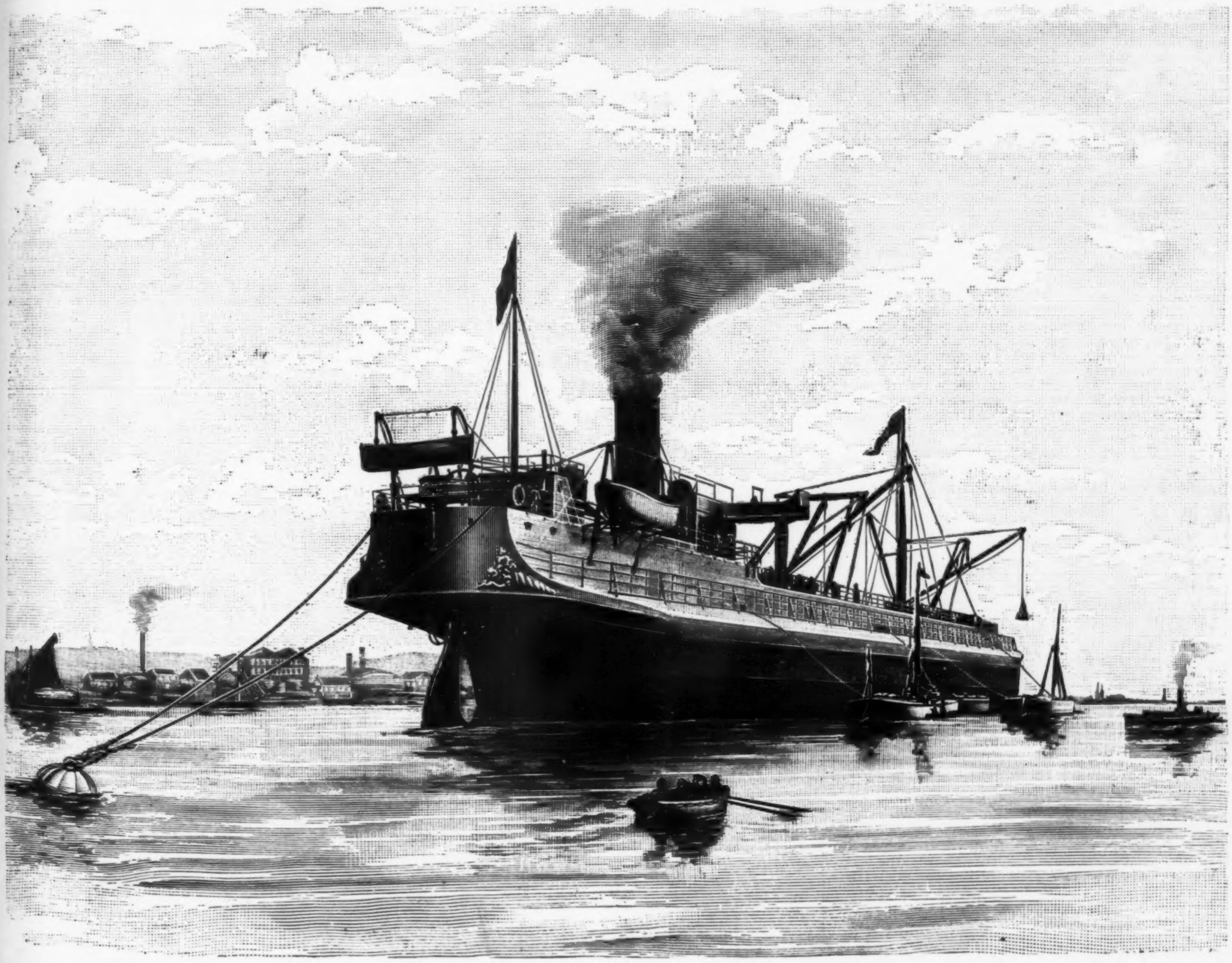
GREAT departures in naval architecture or in marine engineering are rare. There is existing in both these scientific industries a widespread conservatism, and designs embodying radical changes are few and far between. No doubt the mail and passenger, and even cargo steamers of to-day, and their engines and boilers, are vastly different from those of the same classes constructed a quarter of a century ago, but what are styled "modern" vessels and engines have assumed their present features by gradual stages, as though in ship building and marine engineering there were laws of evolution. No doubt several exceptions to this general tendency might be particularized. However, it must be questioned whether there has ever been such a notable instance as in Doxford's patent "Turret" cargo steamer. It is therefore with special pleasure we present our readers with a supplement illustrative of this most recent departure in naval architecture, which promises to meet with a speedy and extensive adoption, both at home and abroad, experienced shipowners, convinced of its undoubted advantages, being on the point of acquiring cargo steamers of Doxford's patent "Turret" type.

It will be observed from our illustration that the principal feature in this new design of dead weight carrying steamer is the novel above-water appearance. Up to the load water line there is no material difference between Doxford's patent "Turret" steamer and an ordinary steamer built on the web frame system with wide spacing of hold beams, a type so deservedly in favor with ship owners, adapted as it is to many varieties of cargo, including machinery of great bulk. Above the load water line, both in the general appearance and construction, there is a great divergence from ordinary practice. Considering the design from a longitudinal point of view, it is noteworthy that in the vessel's deck and upper works there is no sheer, abundant provision for surplus buoyancy being provided without the springing of the ends of the vessel upward, a practice which in some cases has been carried to an absurd extreme. At first sight this deviation from ordinary practice might be considered as resulting in an unshipshaped model, but "Use is second nature," and after viewing a model of Doxford's patent "Turret" cargo steamer, we must frankly confess that the absence of sheer does not appear a drawback.

Another longitudinal feature is the provision of an upper and two lower weather decks, so that it is entirely *erroneous* to describe Doxford's patented design as that of the "whaleback" type, in which one of the great defects is the absence of proper provision for the crew obtaining exercise, and having facilities for passing from one part of the vessel to another. It is far more accurate to compare this new Wearside "Turret" type of steamer with the original spardecker, with rounded gunwale, having a deck house extending all fore and aft, than to consider it in comparison with the American lake cargo steamers. On the lower weather decks, which are each on the same level, but one on the port side and one on the starboard side, are placed timber heads for mooring the vessel, or, as in our illustration, for securing barges or lighters engaged in transporting cargo to and from the vessel. These lower weather decks will be principally used when in harbor, although they are amply provided with rails and stanchions for the safety of the crew. The upper weather deck is of such a width as to admit of a port and starboard passage clear of the hatch coamings, and extends all fore and aft on top of the "Turret." Here are the steam winches, steering gear, windlass, etc. The hatches are of abnormal length and width, and owing to the rounded gunwale and "Turret" erection the holds are emphatically "self-trimmed." It is important to notice that the latter feature makes this new design of vessel specially adapted for grain cargoes.

The steamer we illustrate is designed to carry 4,700 tons dead weight on 20 ft. 3 in. draught of water, and constructed specially for carrying wheat in bulk with a "Turret" providing 5 per cent. grain feeding accommodation, and will only measure 2,850 tons gross register. For ordinary deadweight cargo purposes the size of the "Turret" could be reduced, and then the gross tonnage need not exceed 2,650 tons. Similarly for cargoes of lighter weight and increased bulk, the "Turret" can be made of increased size so as still to secure a deadweight of 4,700 tons, but necessarily on an increased gross register tonnage to approximately 3,000 tons. In each instance the full propelling power deduction of 32 per cent. and crew space is obtainable.

It is also apparent that the "Turret" feature of this design makes it equally advantageous for the oil in bulk trade, and as the engines and boilers are at the extreme after end, both the outward and homeward bunker coals can be stowed close to the engine and boiler space, and separated from the petroleum cargo by a double bulkhead of iron, filled with water, as in coffer dams, and thus complying with the latest requirements of the Suez Canal authorities for this type of vessel. It is evident that for the expansion of the liquid cargo and for oil-feeding provisions, the "Turret" feature of this design gives unlimited scope for the most approved arrangements.



A "TURRET" CARGO STEAMER.

Not only does Doxford's design of a "Turret" cargo steamer give special facilities for a variety of cargoes, but, owing to the continuity of the "Turret" both fore and aft and transverse wise, enormously increased longitudinal strength is provided, an element which has been duly considered by the Committee of Bureau Veritas in arranging the scantlings of this new type of steamer. The port and starboard lower weather decks have no openings cut in them, so that the structure is continuous from the keel to the top of the "Turret." Not only are the shell plating and "Turret" sides unbroken in their continuity, but this is also true of the framing, which from the top of the tank to the upper part of the "Turret" is continuous.

Possibly to the ship owner the fact of superabundant strength is not so apparent an advantage as reduced first cost. Undoubtedly the latter item is of great moment, and it is satisfactory to find that this new departure is economical as to the initial expense. It will evidently be so as to "wear and tear," an item which has bulked largely in some recently built vessels, as the absence of "breaks" in the deck line, or of loss of strength due to openings for hatches to the bunkers, grain feedings, etc., near to the gunwale of the vessel, and the utilization of the hatch coamings as an element of strength, must render the vessel less liable to damage by straining.

The details have also been carefully matured in order to obtain a thoroughly seaworthy vessel. A high platform is provided, so that a dry deck is not out of the question, as in many ordinary cargo steamers. At the fore end of the "Turret" deck a breakwater is fitted, so obviating the possibility of having the deck swept by a heavy sea. Not only has a maximum amount of surplus buoyancy been provided, but the equally important *desideratum*, a large righting angle, has been obtained, whether the vessel be in loaded or in light trim. When in ballast and with full bunkers, the propeller will be well immersed. The vessel has an entire double bottom on the cellular system, and with specially subdivided tanks at the after end, so that without endangering the vessel water can be admitted to compensate for the consumption of the coals, and thus maintain a trim of at least 3 in. by the stern.

There is ample space in the "Turret" for accommodation of the crew, either at the fore or at the after end of the vessel. A deck house is provided for the captain, and chart room under the flying bridge; and further aft, just abaft the engine room skylight, is the galley and entrance to the officers' and engineers' rooms, all of which are inside the "Turret."

Owing to the great length of the hatches, which extend practically the full length of the holds, it has been necessary to make special arrangements for their security. Every 20 ft., deep thwartship hatch beams are riveted securely in place, but these can be readily removed by cutting away the rivets, if machinery or other bulky cargo should render it necessary. As already indicated, the usual machinery for working the hatches is provided, and when desired derrick posts with telescopic poles for signaling purposes, and derricks complete with all gear, as fitted by Messrs. Wm. Doxford & Sons, Limited, to the cargo steamers of the British India Steam Navigation Company.—*The Marine Engineer.*

THE SHIP MARIA RICKMERS.

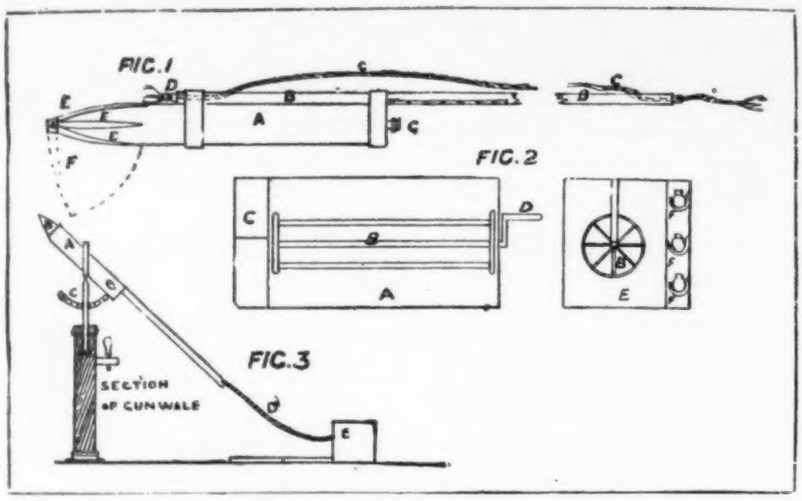
The Maria Rickmers, recently launched by Messrs. Russell, of Port Glasgow and Greenock, for the Bremen firm of Rickmers, claims to be the largest sailing ship in the world. Her dimensions are 375 ft. long, with a beam of 48 ft., and a draught of 25 ft. Her tonnage is 3,822. She is built with double bottom all fore and aft, with deep midship tank for carrying water ballast, and is rigged as a five-masted bark, with double topgallant sails and single royals on four of her masts and skysails on three, carrying altogether a sail area equal to about 57,000 sq. ft.

An unusual feature of the Maria Rickmers is her being fitted with triple expansion machinery of sufficient power to drive her through calms and light winds at a speed of about seven knots, by means of a double-bladed feathering propeller, which will not interfere with the ship's steering when moving under sail alone. The Maria Rickmers is now at sea on the way to Singapore for her maiden voyage. The passage from the Clyde to Barry in ballast was made in 41½ hours, under her own steam. The ship will be usually employed in carrying rice from Burmah to Bremen, where Messrs. Rickmers have large rice mills.

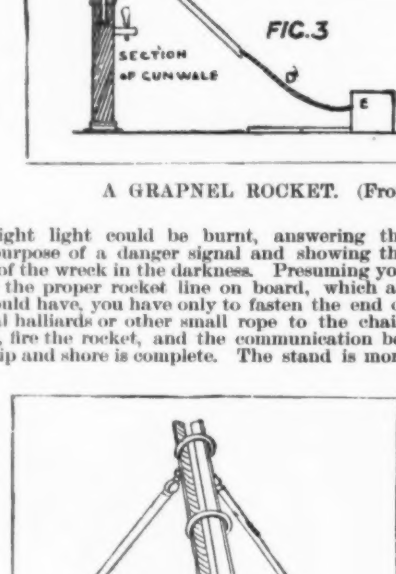
LIFE SAVING DEVICES.*

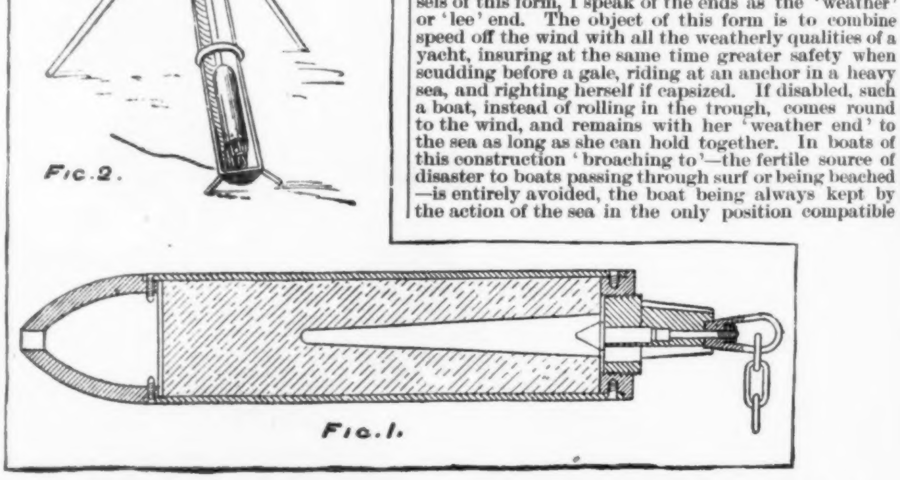
In the designs of Mr. James B. Rodgers, who, by the way, is a coastguard man, Fig. 1 represents the grapnel rocket, stick, and line. A is the rocket, with a range of 500 yards; B B, the stick; C C, inch manila line; D, washers; E E E, the arms of the grapnel shut (four in number); the dotted lines, F, show one arm of the grapnel open; G is the fuse. In Fig. 2, A is a longitudinal section of box 4 ft. by 2 ft. by 2 ft.; B, reel to hold 250 fathoms of inch line; C, space for port fires, fuses, etc.; D, handle for "reeling up;" E is an end section of box, in which B is the reel; F F F, spare rockets. The top and bottom of the box will open as in Fig. 3. In Fig. 3, A is the rocket frame and stand; B, the head of the rocket; C, the elevating arc; D, the rocket line; E, box and reel, with F, showing top and bottom opened right down. The inventor says that the principal part is the "grapnel rocket," which will, when the least strain comes on it after reaching the shore, "bite" like an anchor. By this means communication can be retained until assistance arrives, or a boat might be hauled ashore by it. The frame might be fixed by unshipping a belaying pin and putting the stand in its place.

In describing the rocket invented by Mr. Singleton Hooper, which is to be sent from the ship, we cannot do better than quote his description. He says: "Every vessel should be compelled to carry a few of these rockets and a stand, for she may not be wrecked when under the nose of a coastguard station or near a lifeboat manned for her relief. The power of this rocket is so great that it carries its line with the greatest degree of certainty, and entirely supersedes 'the old stick rocket,' which is well known (to the cost of many valuable lives every year) as being most erratic in its flight. The line cannot possibly coil, as the double swivel by which it is fastened to the rocket is a certain preventive; neither can it be burnt by the back fire. A shell can be fitted to it, from which a magnesium or other bright light could be burnt, answering the double purpose of a danger signal and showing the position of the wreck in the darkness. Presuming you have not the proper rocket line on board, which all ships should have, you have only to fasten the end of the signal halliards or other small rope to the chain attached, fire the rocket, and the communication between ship and shore is complete. The stand is more simple still. A couple of pieces of wood or the bottom boards and stretchers of a boat will easily form a V-shaped stand, and from this the rocket can be fired. Fig. 1 shows a section of the rocket, Fig. 2 the rocket on its stand ready to be fired."



A GRAPNEL ROCKET. (From designs by Mr. James B. Rodgers.)

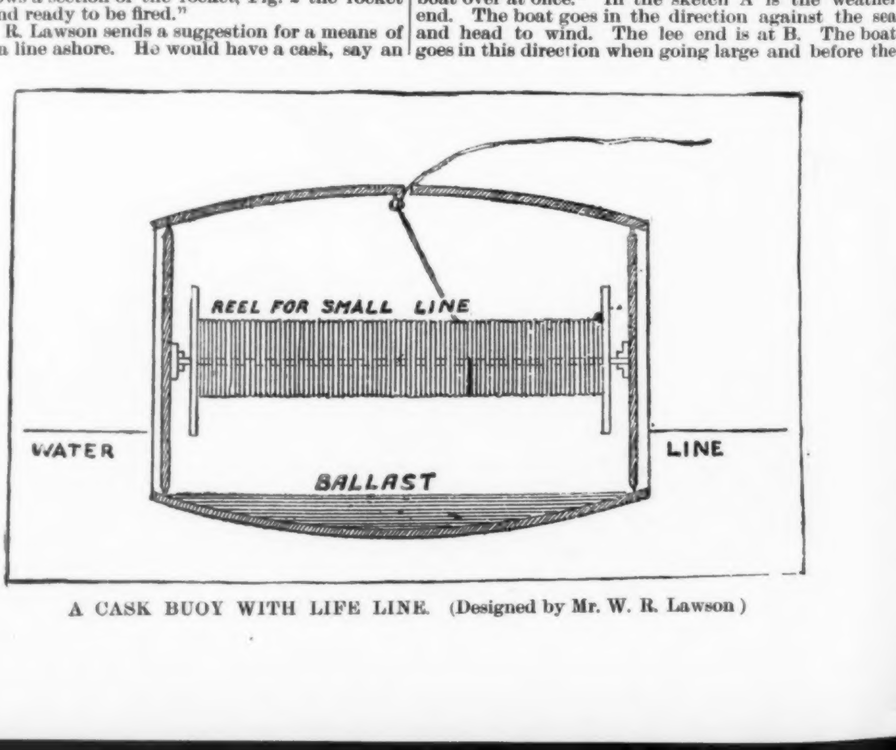




LIFE SAVING ROCKETS. (Patented by Mr. J. Singleton Hooper, Retired Fleet Paymaster, R. N.)

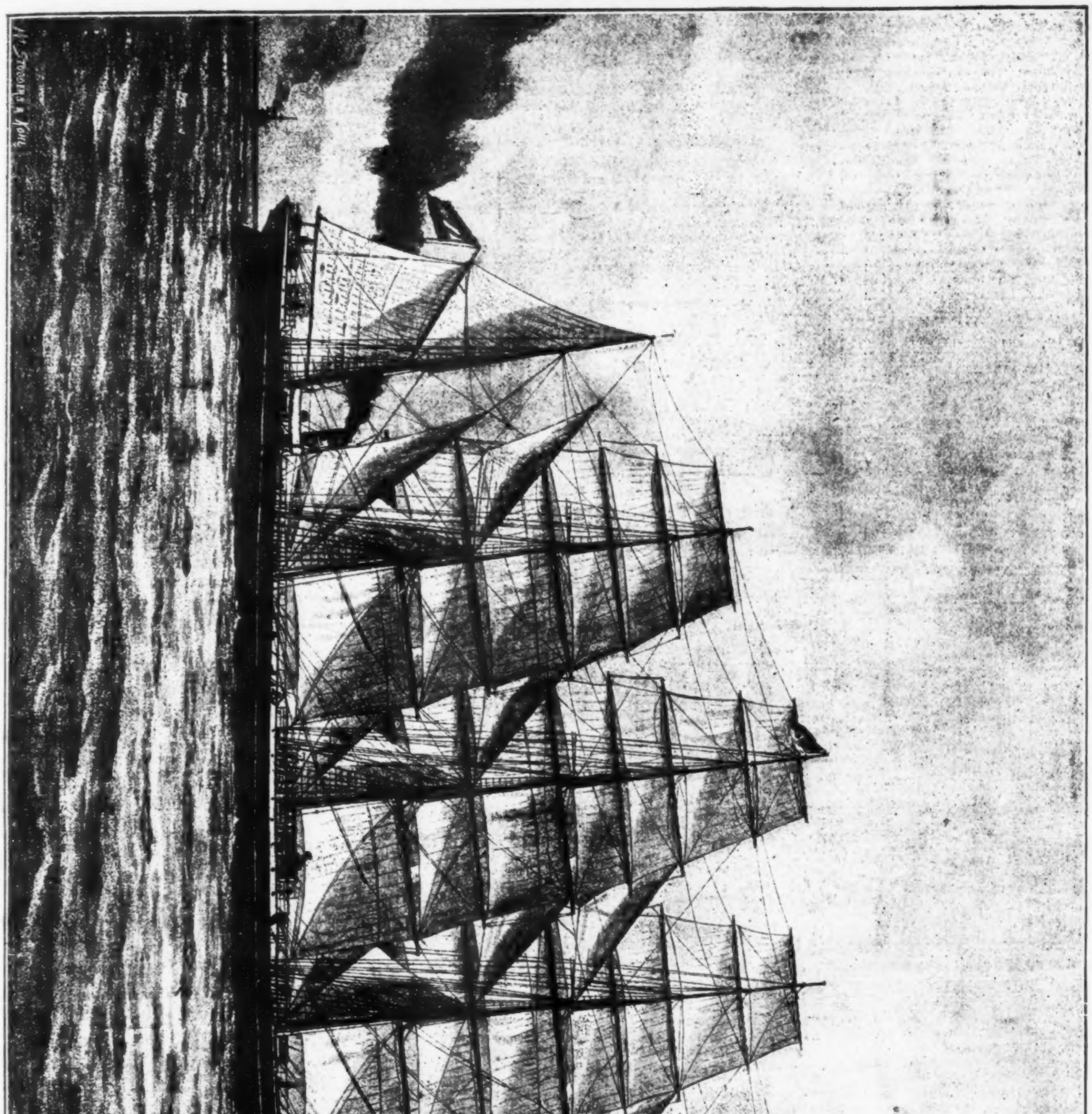
Mr. W. R. Lawson sends a suggestion for a means of carrying a line ashore. He would have a cask, say an old pork cask, used with some iron or lead ballast, secured at one side, so as to keep a small bung hole always uppermost. A deep sea lead reel would be fixed inside the cask with the line reeled on and brought through the bung hole. When the end of the line is secured on board, and the cask thrown overboard, it should blow or wash rapidly ashore, while the line would unreel itself and offer less resistance than if it were dragged through the water from the ship by the cask.

Mr. John Coryton, who has long studied the subject of ship and shore communication, sends us various suggestions. We give to-day several sketches from Mr. Coryton's designs. Two are of a lifeboat. "Lifeboats," he suggests, "should be built double ended. The advantage of this form consists in combining in one vessel the best qualities of two different kinds of vessel—those that sail best on a wind or steam best head to wind, and those that go best off the wind. The ends of the boat represent respectively the entry lines characteristic of these classes, and the vessel proceeds with one or other end foremost, according to the direction of the wind and the vessel's course. In rivers or smooth waters she proceeds as if going off the wind. The terms of bow and stern being inapplicable to vessels of this form, I speak of the ends as the 'weather' or 'lee' end. The object of this form is to combine speed off the wind with all the weatherly qualities of a yacht, insuring at the same time greater safety when scudding before a gale, riding at an anchor in a heavy sea, and righting herself if capsized. If disabled, such a boat, instead of rolling in the trough, comes round to the wind, and remains with her 'weather end' to the sea as long as she can hold together. In boats of this construction 'broaching to'—the fertile source of disaster to boats passing through surf or being beached—is entirely avoided, the boat being always kept by the action of the sea in the only position compatible with safety. When the boat is capsized, her anchor slips from a pin and falls overboard. As soon as it touches ground it holds, and the leverage cants the boat over at once." In the sketch A is the weather end. The boat goes in the direction against the sea and head to wind. The lee end is at B. The boat goes in this direction when going large and before the



A CASK BUOY WITH LIFE LINE. (Designed by Mr. W. R. Lawson.)

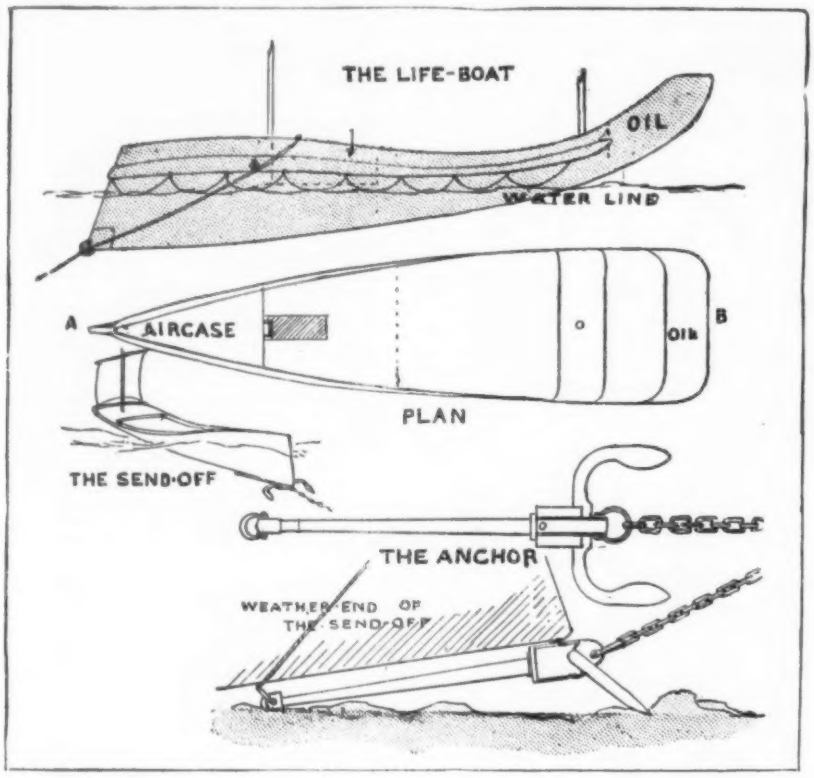
* Continued from Supplement, No. 852, page 13616.



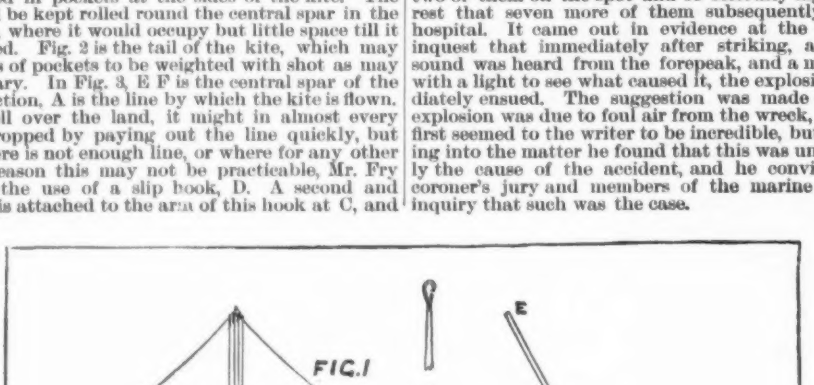
THE GERMAN SAILING SHIP MARIA RICKMERS, AUXILIARY POWER, FIVE MASTS, 6000 TONS CAPACITY.

wind. The "send off" is intended for use where the crew cannot launch their boats, and no assistance is forthcoming from the shore. The "send off" suggested by Mr. Coryton is a diminutive form of the lifeboat described above, and has the same qualities. It will go any distance dead to leeward, carrying a double line, beach itself without broaching to, and lodge an anchor at high water mark. The Coryton anchor shown affixed to the weather end of the "send off" is peculiar in construction. The head or holding part, as well as the palms, are turned the reverse way to that of an ordinary fluke anchor. The cable chain is made fast by a shackle to the head end, and the buoy rope to the other end of the shank. The shank is formed of two parallel pieces of iron, held together by screw bolts and nuts. The head turns about 30 deg. each way, and is stopped in the required position against two shoulders on the shank. It is claimed for the anchor that it bites readily, and having once bitten, is driven further into the ground by any strain the cable may bring to bear upon it, and that it is more easily drawn when the cable in weighing is brought into a vertical position.

Mr. O. A. Fry sends us the following "simple and practical" suggestion for effecting communication. He says the difficulty of communicating with the ship from the shore is enhanced by the necessity of being able to steer the line carrier, which difficulty does not exist when the ship sends the line ashore. Mr. Fry proposes to utilize the wind. In the accompanying sketches Fig. 1 is a large kite, some eight feet in height. The central span is permanently attached to the canvas body of the kite, and the cross spar is put through a ring attached to the central spar, the ends being fixed in pockets at the sides of the kite. The kite could be kept rolled round the central spar in the flag room, where it would occupy but little space till it was needed. Fig. 2 is the tail of the kite, which may be a series of pockets to be weighted with shot as may be necessary. In Fig. 3, E F is the central spar of the kite in section, A is the line by which the kite is flown. When well over the land, it might in almost every case be dropped by paying out the line quickly, but where there is not enough line, or where for any other possible reason this may not be practicable, Mr. Fry proposes the use of a slip hook, D. A second and finer line is attached to the arm of this hook at C, and this being led through the ring, B, will travel to the ship's deck. When it is desired to lower the kite ashore, a jerk given to this line would release the stouter line A D, and the kite, being held only by its upper brace, would capsize and fall headlong to the earth. The hook might be bound lightly to the spar of the kite at H by a strand which would break when leverage strain was put on the end of the arm.



THE CORYTON LIFEBOAT—"SEND OFF" AND ANCHOR. (From designs by Mr. John Coryton.)



ANOTHER KITE SUGGESTION. (From sketches by Mr. O. A. Fry.)

SINGULAR ACCIDENT TO A STEAMER.

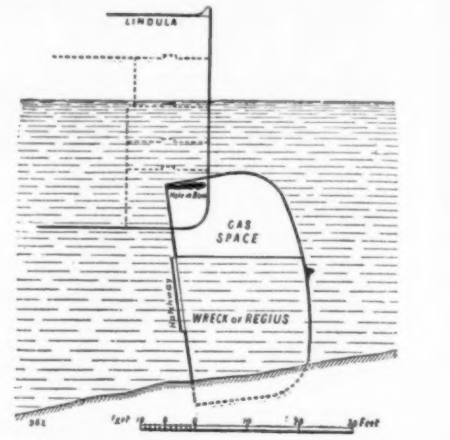
AN accident took place recently in the River Hooghly, at Calcutta, to one of the British India steamers, through which nine persons lost their lives.

A correspondent of *Engineering* describes the occurrence as follows: On July 3, 1890, the s.s. Regius was sunk at her moorings in Garden Reach by another ship running into her. The Regius was to have gone to sea the following morning with a full cargo of tea, oil seeds, rice, etc. She sank well out of the channel, but so close under the bank, near to which extensive cotton mills stand, as to render it impossible to cut up the wreck by explosion without incurring serious risk of injury to the buildings and machinery of the mills. It was therefore determined to leave the wreck as it lay, duly marked with buoys. The least depth over it was about 12 ft. at lowest low water.

On January 13, 1892, the s.s. Lindula was just about being turned on the last of the ebb tide preparatory to leaving the port. She struck the sunken wreck with her bow, and within a very short time, variously estimated by the different witnesses at 45 seconds to 4 minutes, an explosion occurred in her forecastle, where the crew were at the time having their breakfast, which killed two of them on the spot and so seriously injured the rest that seven more of them subsequently died in hospital. It came out in evidence at the coroner's inquest that immediately after striking, a rushing sound was heard from the forepeak, and a man going with a light to see what caused it, the explosion immediately ensued. The suggestion was made that the explosion was due to foul air from the wreck, which at first seemed to the writer to be incredible, but on looking into the matter he found that this was undoubtedly the cause of the accident, and he convinced the coroner's jury and members of the marine court of inquiry that such was the case.

It had for some time been observed that air or gas was continually bubbling up over the wreck of the Regius, and after the Lindula struck it the emission of gas was much more lively over the part where the wreck had been struck. The writer collected a quantity of this gas and found it to be light carbureted hydrogen or marsh gas, with the well known properties of burning with a bluish light, and forming an explosive mixture with air, the proportions producing the maximum explosion being one of the gas to ten of air. This gas is an invariable product of the decomposition of organic substances such as the cargo of the Regius had been composed of.

The Lindula having been put into dry dock, it was found that she had a large hole torn in either bow, aggregating 7½ sq. ft. in area, and examination of the wreck by divers showed that the Lindula had cut into it in the way shown in the diagram. It is easily seen that in consequence of the inclined position of the upper or starboard side of the wreck, the holes torn in the bow of the Lindula, when cutting through the angle formed by the deck and side of the wreck, immediately afterward passed into the inside of the wreck, the upper portion of which down to the hatchway was doubtless full of gas under a pressure due to about 30 ft. of water, the depth at the time above the starboard coaming of the hatch. This pressure would cause the gas to rush with great velocity through the rents in the bows of the Lindula, and very few seconds would



suffice to supply the quantity necessary to form an explosive when mixed with the air in the forepeak. The cubic contents of the forepeak was 3,200 cubic ft., so only 320 cubic ft. of gas would be required to produce the deadly compound, to which the light needed to produce the explosion was promptly supplied by a man coming to see what was the cause of the rushing noise observed immediately after the ship had struck the wreck.

As the wreck of the Regius cannot be removed, measures are being taken to pierce several holes in her upper side to allow of the accumulated gas escaping.

[Continued from SUPPLEMENT, No. 853, page 13627.]

A SHORT HISTORY OF BRIDGE BUILDING.*

By C. R. MANNERS.

GERMANY has been called the school for timber bridges, as England is for those of iron. One of the finest specimens of wooden bridges ever erected was the truss bridge over the Limmat (Fig. 70), at Wittengen, built in 1758 by the brothers Grubenmann, self-taught village carpenters. It had a span of about 390 ft., the longest ever crossed by timber, with a rise of 43 ft. Unfortunately it was burnt about the beginning of this century. The same carpenters, at about the same time, also erected the Schauffhausen Bridge over the Rhine (Fig. 71), which took the place of a stone bridge, the piers of which had been undermined and fell in 1754. This bridge had one span of 193 ft. and another of 172 ft., and was destroyed by the French troops in 1799. In the early stage of railway construction the Germans built several fine timber bridges, but I believe they are now inadmissible in railway practice in that country and have been superseded by iron.

The Americans, having a plentiful supply of timber, adopted that material largely for bridge construction. The Great Portage Viaduct, Fig. 72, 800 ft. long, over the Genesee River in the State of New York, was 234 ft. high. The piers, nine in number, were 190 ft. high and built up of great timber framework well braced together. This viaduct was built in 1852 and destroyed by fire May 6, 1875. The first designs were generally on the lattice principle, but this proved insufficient for heavy trains and has been abandoned.

The Howe bridge became extensively used on the railways in the States. It is light and simple in construction, and stands well for spans up to 100 ft. The construction is similar to the improved Howe truss, but without the arch (Fig. 73).

For large spans the improved Howe truss came into very general use. This is a combination of the simple Howe truss with the arch. There are two outside and one center trusses, with an arch on each side of each truss. Then came the inflexible arched truss (Fig. 74).

Timber was also much used in Spain for bridge building. In 1849 a fine example of the timber lattice girder was erected over the Msta, on the St. Petersburg and Moscow Railway. It had nine spans of 199½ ft. each, with three lines of girders 21 ft. deep and upward of 100 ft. above the river.

In the early days of railways timber bridges were frequently used in England, many of which were on the truss system so much used in America. Others were on a system of combining planks in layers, curved to form arches and much like what is now known as the bowstring girder, and in some cases the roadway was suspended from an arch, as in the case of the bridge over the Delaware at Trenton, in New Jersey, built by Mr. Burr in 1804. This bridge had openings from 160 ft. to 200 ft., spans with horizontal tie beams

* From *Engineering*.

to prevent the arches from springing (Fig. 75). The first of the kind was erected on the Ancholme in 1826, when a bridge of 100 ft. span was successfully constructed.

The forms of timber bridges from plain beams, trusses of different kinds, and of arches and combinations of two or more systems, have been very numerous. Timber bridges, however, quickly decay and become unsafe after some fifteen years' wear and tear. In America and Switzerland they were often roofed over, with a view to protecting them from the weather. Many instances have occurred of accidents through decay and from fire. Only the other day a train fell through an American trestle bridge and several lives were lost.

The introduction of the railway system and the

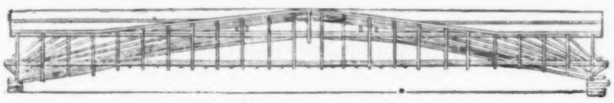


Fig. 70. Bridge over the Limmat.

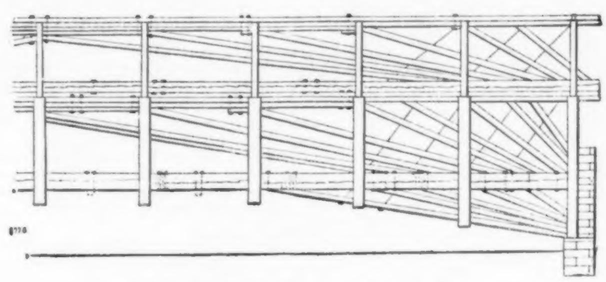


Fig. 71. Bridge of Schauffhausen.

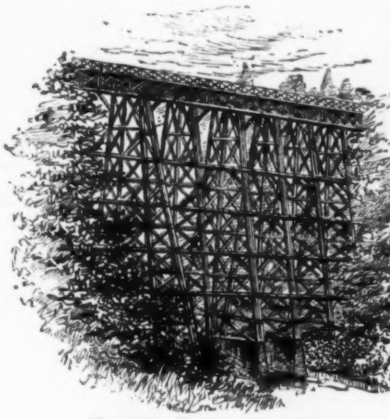


Fig. 72. Portage Bridge.

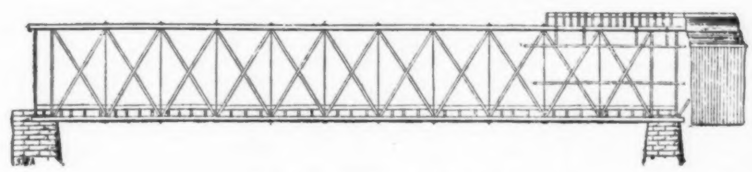


Fig. 73. The Howe Bridge.

Fig. 76.

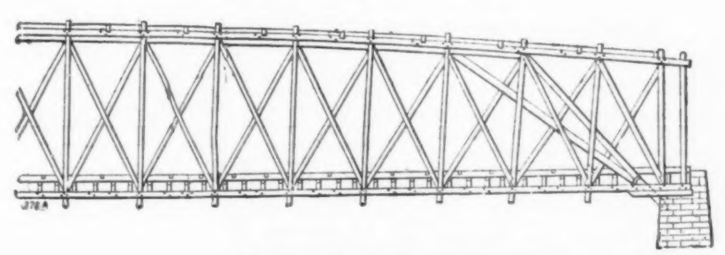


Fig. 74. The Inflexible Girder.

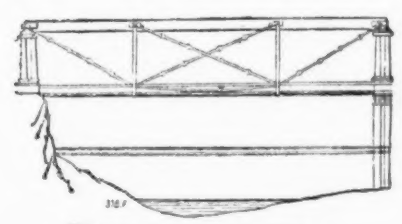


Fig. 80. Chepstow Bridge.

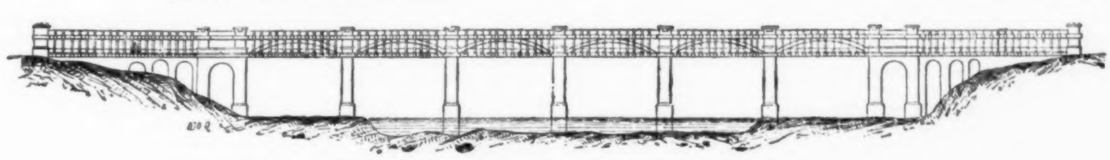


Fig. 79 High Level Bridge: Newcastle-on-Tyne.

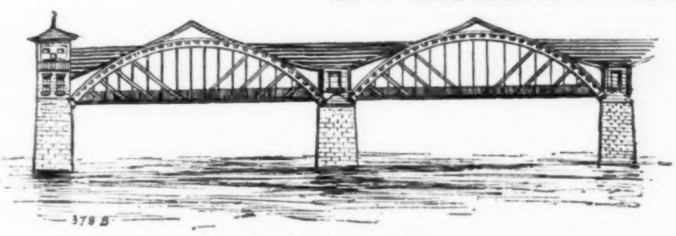
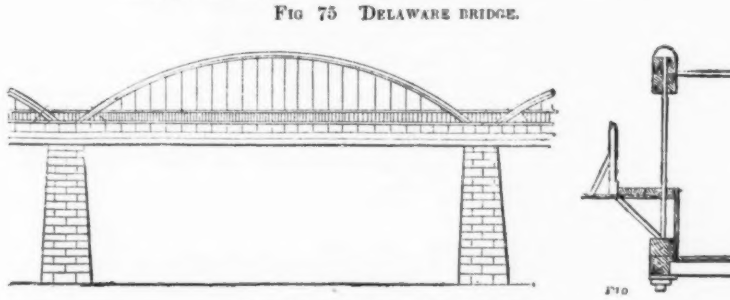


Fig 75 Delaware Bridge.



Figs. 77 and 78. Jordan's Girder.

A SHORT HISTORY OF BRIDGE BUILDING.

rapid decay of timber, destruction by fire, and other risks, necessitated the use of some other material. Iron was introduced, and truly gigantic strides have been made during the last half century in the use of this material.

The earliest iron bridges were arched, about which I have already spoken. Arches, however, are inapplicable in many cases in railway practice, and a new departure in bridge building was necessitated. The first use of the simple cast iron beam, or girder, was by Telford, in building some cotton mills at Salford in 1800, but George Stephenson was the first to apply it to bridge construction on the Liverpool and Manchester Railway. The simple form of the early girder can scarcely now be recognized in the magnificent structures which are so general in all civilized countries. Architects and engineers seem to have reversed the order of progress. In architecture the beam or lintel was the characteristic of the early temples, but the arch seems now to have almost entirely superseded it, whereas in engineering the arch took the prominent position in the early works, and we now seem to have come back to the old beam. The simple form of the early cast iron beam, the straight bottom flange and the vertical web connecting it with the curved top flange, is familiar to all (Fig. 76).

The difficulty of obtaining abutments capable of resisting the thrust of the large arch, when the use of iron allowed of a great reduction in the rise of the arch, led to the addition of a tie to resist the thrust, and so throw a vertical pressure upon the piers and abutments. They introduced the bowstring girder, which may be called the transitional form between the arch and the beam.

So far as I am aware, Mr. James Jordan's patent of 1796 (Figs. 77 and 78) for suspending the roadway from an overhead arch, is one of the earliest proposed introductions of the principle of the bowstring girder. Among other advantages of his system he states there will be no lateral, but only a perpendicular pressure on the buttresses, walls, or other end supports. Fig. 77 is an elevation and Fig. 78 a transverse section of a one span bridge as shown on drawing attached to his specification. The top and bottom members may be of timber or cast iron. The sketch represents a span in timber and shows an arch built up in layers of planks. Mr. Jordan also claims the advantage of being able to introduce a drawbridge into any span of a viaduct erected on his system. For this purpose he introduces an iron framework under the center portion of his arch to preserve its form as the bottom member is severed. A portion of the roadway is formed so as to be raised by chains from the arch in the ordinary manner of the old drawbridge.

The earliest bridge erected on the bowstring principle was one over the Regent's Canal, at London, on the London and Birmingham Railway, but the finest example in this country is the High Level Bridge, at Newcastle-on-Tyne, which is shown on sketch, Fig. 79. It crosses the Tyne and unites the towns of Newcastle and Gateshead. This bridge was opened in 1849, Messrs. George and Robert Stephenson being the engineers. The cost of conveyance of passengers and merchandise between these towns by the old bridge had reached the great sum of 1,000*l.* per week, so that the local authorities gladly co-operated with the railway company in constructing a bridge to serve both purposes. The center portion of the bridge is in six spans of 125 ft. each. The abutments and piers are of stone. The foundations are on piles, many of them 40 ft. long, driven down to the rock. They were driven by Nasmyth's steam pile driver, which had just been brought out, and so rapid was its action that several of the pile heads took fire. There are four cast iron arched ribs with horizontal wrought iron tie bars to each span. The upper road, which is the railway, rests upon the arches, and the carriage road is suspended from them by wrought iron rods. The depth of the arch at the crown is 3 ft. 6 in., and this slightly increases toward the haunches. The cost was 243,000*l.*

Cast iron was only used for girders on their first introduction, and they were of necessity limited to moderate spans, and it became imperative to strengthen the bottom flange to resist tension. This was done by the addition of wrought iron tension rods, and trussed girders were introduced, one of the earliest examples being a bridge of 63 ft. span, by Mr. Bidder, to carry the Blackwall Railway across the Minories in London. Each girder is in three castings and about 3 ft. deep. To relieve the tensile strain on the bottom flange, wrought iron rods, 5 in. by 1 in., were placed on each side of the girders. These rods are horizontal along the bottom flange of the center casting, and then rise diagonally, and are attached to the top flange at the ends of the girders.

The Chepstow Bridge, Fig. 80, by Mr. Brunel, is on this principle. There are two spans, one of 100 ft., crossed by an ordinary wrought iron girder, and the other 305 ft. span, crossed by a trussed girder, the upper member of which is a horizontal cylindrical

wrought iron column or strut, 9 ft. in diameter, resting on towers at each end. The truss is arranged in similar manner to that already described.

(*To be continued.*)

MECHANICS APPLIED TO THE ROPE AND PULLEY.

THE rope in itself is only intended to transmit a pulling force from one object to another, but by the aid of guide wheels the tension of the rope is brought into use by passing the rope back and forth a number of times

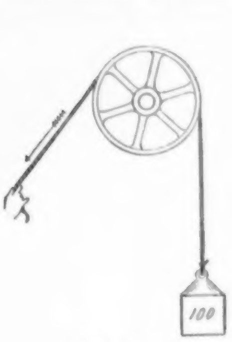


FIG. 1.

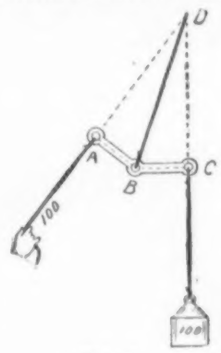


FIG. 2.

till there are folds enough with the combined tension to overcome all the resistance required.

We will start with a rope laid over a single pulley, as shown in Fig. 1. If resistance of all kinds is left out of account, a weight of 100 lb. will produce a tension that will be transmitted by means of the rope over the wheel to the object on the other side, which is supposed to resist its action.

As long as the wheel is standing still it is evident that a bent-arm lever could be substituted in its place, like the one shown in Fig. 2, from A to C, having B for its

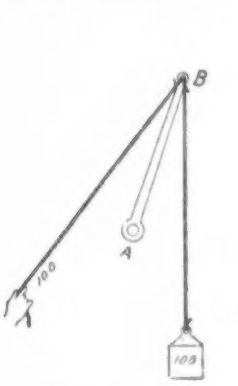


FIG. 3.

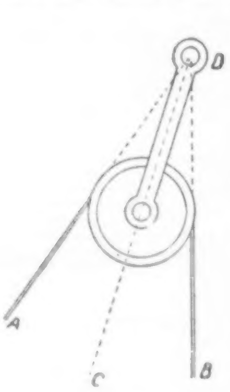


FIG. 4.

fulcrum or point of support. From what has been shown heretofore, it is evident that the line of action from both, at A and C, can be extended till they meet at D, from which point a rope can be fastened and connected with the fulcrum at B, leaving the lever undisturbed, yet suspended from one end of a rope that is arranged to draw in just the right direction for this position.

Instead of a supporting rope attached to the point, D, the transmitting rope could be extended till each fold met at the same point and a support arranged, as shown in Fig. 3, from A to B, which will support the

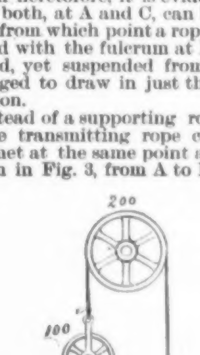


FIG. 5.

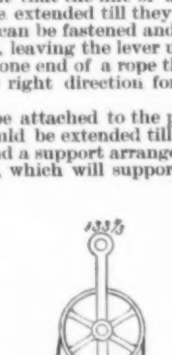


FIG. 6.

weight just as though a wheel was used, as long as the system remains under a standing strain.

It is plain from these illustrations that in suspending a pulley for a rope to run over, it may be connected with any object if it will only come in line with the point where the lines of action on both sides of the wheel meet like the wheel shown in Fig. 4.

As to the leverage that may be obtained with a rope and pulley, it will be seen that one arm of the mathematical lever is just as long as the other, and the only way of multiplying the driving force is by arranging one lever to lift under an arm of the other. This may be done first by arranging the ropes and pulleys as shown in Fig. 5, where a force of 200 lb. is exerted by a pull of only 12½ lb., the first pulley acting as a snatch on the end of the rope that passes over the next wheel, and so on till enough driving force is obtained to raise the 100 lb. weight.

Another method of arranging the mathematical levers would be to set them side by side, each taking their share of the load which would fold up a single rope similar to the one shown in Fig. 6, where the load would be divided equally among each stretch of rope, if friction were left out of the calculation.

In Fig. 7 is seen a single rope snatch used for taking the strain from a chain hook for an instant, where a

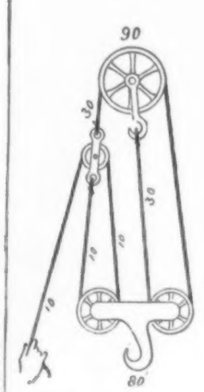


FIG. 7.

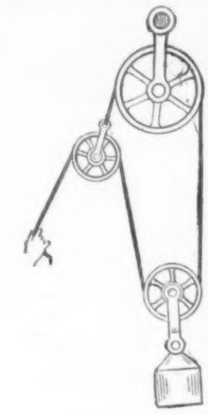


FIG. 8.

force of 10 lb. will sustain a load of 80 lb., or in the ratio of 1 to 8.

There are many rules for figuring the power of ropes and pulley blocks, but in complicated cases it is best to sketch out the entire system and start with a known force and write its tension on each fold, as it would appear if friction were left out of account, and then add up all that are assisting in raising the load, and see how the sum compares with the force we have to work with. The system shown in Fig. 8 is given to apply this rule to, which will show at once that such an arrangement of pulley and ropes could not sustain a load a great while without its settling to the ground again, yet it is one that has been strung up several times in the hopes of getting a snatch on a rope from one of its own ends.—*Boston Journal of Commerce.*

PETROLEUM AS A FUEL.

THE trials recently conducted at Spezia, by Admiral de Sambuy and a special commission, are of far greater value than their stated object would seem to imply. Our knowledge of the extent of our coal fields and of the enormous annual consumption of coal justifies the belief that within no very distant period that fuel will become unobtainable except at a price that will place it beyond the reach of the ordinary manufacturer. Mr. Price Williams has shown by calculation that the workable resources at present known to exist will be exhausted within a comparatively few years if the present annual consumption of nearly eighty million tons be maintained. The newly opened up coal fields in Kent were not taken into consideration when the calculation was made, but it is improbable that these thin seams will materially affect the accuracy of the deduction. The anticipated exhaustion of our coal supplies does not, however, excite the apprehension that it did a few years ago. Coal had its origin in the petrifaction of submerged forests, and by the decomposition of marine plants another useful fuel has been given to us, namely, petroleum. It will be as well to direct our attention to the difference in the chemical composition and the specific gravities of these two fuels, coal and petroleum. The average composition of 28 samples of Lancashire coal is: Carbon, 78; hydrogen, 5·28; oxygen, 9·5; while that of petroleum refuse is: Carbon, 87·1; hydrogen, 11·7; oxygen, 1·2. The vastness of the oil fields already discovered in various parts of North and South America, Russia, India, and Persia makes the liquid hydrocarbon petroleum, with its high calorific power, a formidable competitor with coal, and it must ultimately take the place of the latter in manufacturing processes and for domestic use. Those who had knowledge of the results of the experiments made as to the efficiency of petroleum as fuel for locomotives on the Grazi and Tsaritsin Railway in southeast Russia in 1883, and the Buenos Ayres and Rosario railways in 1887, were not surprised at the satisfactory report of the trials made by Admiral de Sambuy. In these experiments petroleum refuse (*astaki*) only was used, its calorific power being once and a half greater than that of coal. The petroleum oil, which is obtained by a process of distillation, has a calorific power nearly twice that of petroleum refuse, and therefore about two and a half times that of coal. But the value of a fuel to the manufacturer depends upon its evaporative power, and in this respect petroleum is, as of course its heating power indicates, superior to coal. At an effective pressure of eight and a half atmospheres the theoretical evaporative power of good English coal is 12·16 lb. of water per lb. of fuel, while at the same pressure petroleum refuse has a higher evaporative value of about 33 per cent.

Again, in the case of coal no less than 40 per cent. of the heating power, theoretically considered, is unavoidably lost through imperfect combustion, while with petroleum 75 per cent. of the theoretical evaporative power is effective. As Mr. Thomas Urquhart has clearly demonstrated, the practical evaporative value of petroleum as compared with that of anthracite coal is, weight for weight, from 65 to 75 per cent. higher. As a fuel for steamships pretroleum has a decided advantage in the matter of storage room, eight cubic feet less per ton being necessary; but the danger of carrying large quantities of such an inflammable article more than counterbalances the advantage gained in storage. The relative cost of these fuels is at present in England greatly in favor of coal, but it may be confidently predicted that with the improvements in the means of production inevitably resulting from an increase in the demand, petroleum will as regards price, as it is in other respects, be a successful rival of coal. In Russia, where some of the experiments I have alluded to were made, the price of the petroleum refuse was below that of coal, being 21s. per ton, while coal was 27s. 3d. per ton. Whereas 12,639 lb. of anthracite coal were consumed in running 194 miles with a gross load of 400 tons, only 7,223 lb. of petroleum refuse was found necessary to run the same distance with the same load. The cost was, therefore, a little more than 4d. per mile when the petroleum refuse was used, and 9¼d. fully per mile when coal was used. Strikes, short weight, and the numerous other eccentric motions of the wheel of coal commerce are hastening on the adoption of other substances to work out our purposes in the various manufactures and to supply our domestic wants.—*Chem. Tr. Jour.*

INSTRUMENTS FOR DRAWING CURVES.

By Prof. C. W. MACCORD, Sc.D.

XI.—THE ELLIPSE.

FIG. 1 is a skeleton diagram of the familiar elliptic trammel; the points A B slide respectively along the lines of the major and the minor axes, and the point P, upon the prolongation of B A, traces the ellipse shown, whose semi-minor axis is equal to P A, the semi-major being equal to P B.

Drawing through the sliding points A and B lines respectively perpendicular to their paths, the intersection O of these perpendiculars is the instantaneous axis of the trammel-bar, and O P is normal to the ellipse at P.

Ordinarily, the pen is rigidly fixed to the trammel-bar, the faces of the blades being perpendicular to P B; so that the marking edges are tangent to the curve only when the bar coincides with one of the axes. For this reason the common elliptograph, constructed upon this principle, cannot be relied on to draw a smooth line in ink unless the eccentricity of the curve is quite small.

In order to work correctly in all positions, the edges of the pen ought, clearly, to be kept always perpendicular to the normal P O, whose position relatively to P B is continually changing; and this may be accomplished in the following manner:

Drawing in Fig. 1 the straight line O C, the diagonals of the rectangle O B C A are equal, and they mutually bisect each other in D. And since A B is constant, O C is also constant; hence during the motion of the trammel-bar the points D and O must move in circular paths with the same angular velocity, and in the same direction.

Then in Fig. 2, let the crank C D O turn on the fixed center C; this crank is jointed at D to the bar P D, of which the point A slides on the horizontal axis as before; A D, C D, and D O being equal to each other as in Fig. 1. Any point P on the prolongation of D A will then trace an ellipse, the action being identical with that of the first device.

But the pen, instead of being rigidly fixed to the trammel-bar, is provided with a cylindrical shank turning freely in a socket which is clamped to, and carried by, that bar. This shank, projecting above the socket, is transversely drilled, in a direction perpendicular to the faces of the pen blades, for the introduction of a bridle-rod P O, which passes through a corresponding hole drilled through a pen similarly fitted to turn in a socket at O in the crank-arm C D O. The path of the pen, therefore, is determined by the trammel-bar exactly as in Fig. 1, and must, consequently, be a true ellipse; but the direction of the marking edges is controlled by the bridle-rod, so as always to be tangent to this path, whence the result must be a smooth line, whatever the eccentricity of the curve.

Another method of accomplishing the same object is shown in Fig. 3, where P A B is a trammel-bar, whose motions are controlled by the sliding of the points A and B along the horizontal and vertical axes, as in Fig. 1. This bar is jointed at B to another one, E B R, the point E of which also slides along the horizontal axis, and B E is equal to B A. The length of B R depends upon the following construction: Draw through A and B perpendiculars to their paths, thus locating the instantaneous axis O of the trammel-bar P B, and draw the straight line C O, all as in Fig. 1; finally, draw P O and produce it to cut the prolongation of E B in the required point R.

Since the line C O bisects A B at D, and A E at C, it is parallel to E B R; therefore the triangles P B R, P D O, are similar, whence

$$BR : DO :: PB : PD;$$

which gives, since D O = A D, the value

$$BR = \frac{PB \times AD}{PA + AD} \qquad (A)$$

or, doubling both terms of the fraction,

$$BR = \frac{PB \times AB}{2PA + AB} \qquad (B)$$

which may be written

$$BR = \frac{PB \times AB}{2PA + (PB - PA)}, = \frac{PB \times AB}{PA + PB} \qquad (C)$$

When the mechanism, thus adjusted, is set in action, the point R traces one ellipse and the point P traces another, and we have the curious relation between them, that the line P R joining the generating points is always normal to the second curve; and is, therefore, the center line of the bridle-rod by which the marking edges of pen at P are kept always tangent to the ellipse.

It will readily be seen that in constructing a practical elliptograph on either of these plans, the various pieces must be arranged to move in different planes in order to avoid interference; this involves some mechanical difficulties, but, nevertheless, it is feasible, and it may be proper to state that the writer some years ago

designed two working instruments of which the movements are shown in Figs. 2 and 3.

The first was a "semi-elliptograph," capable of drawing only one-half of the curve, the apparatus being reversed and set again in position on the opposite side of the major axis in order to draw the other half.

This construction was found advisable on account of the necessity of providing in the frame a fixed support for the center C of the crank in Fig. 2. This device seems at first sight the simpler, but in Fig. 3 this crank is dispensed with, and the movement there shown appeared to present greater facility of construction when the whole curve is to be described by one continuous motion.

In adjusting the first of these instruments to draw any given ellipse, it will be seen that in Fig. 2, P A must be made equal to the semi-minor axis, and A D, C D, O D, each equal to half the difference of the semi-axes. In the adjustment of the second, P A in Fig. 3 must be made equal to the semi-minor axis, A B and B E each made equal to the difference of the semi-axes, while the distance B R must be calculated from Eq. (C) given above; which may be written

$$B\,R = \frac{\text{semi-major} \times \text{diff. of semi-axes}}{\text{sum of semi-axes}}$$

It is easy to see that provision for making all these adjustments, and for avoiding interference of parts during the action, of necessity involves some complication of detail, so that the means by which the object is accomplished can be much more readily explained by aid of these skeleton diagrams, than by representation of the instruments themselves. And this explanation is the sole aim of this paper; for the application of such a bridle-rod is much more likely to be of use in apparatus for other purposes than drawing—as, for instance, the cutting out of oval mats or passepartouts.

A third device, shown in Fig. 4, is based upon the fact that the common elliptic trammel is in effect a planetary wheel-train. Thus if in Fig. 1, the circle described upon C O as a diameter, be supposed to roll inside the circle of which C O is the radius, the points A and B upon the circumference of the former will travel in straight lines through C. Evidently, then, an annular wheel, with a pinion of half its diameter rolling within it, may be substituted for the straight guides. Instead of the annular wheel and pinion, we may use, as in Fig. 4, an externally toothed wheel W, and another one *w* of half the diameter, motion being transmitted from the first to the second by an idle wheel, whose diameter is arbitrary, gearing with both. The bearing of *w* is in a block which slides in a slotted train-arm turning around C the center of W; and the center G of the idler is connected with that of W by a link C G, and with that of *w* by a link D G. So far, the arrangement is substantially the same as that of Suardi's geometrical pen, described in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 470; and wherever D may be placed in the slot, it is apparent that, the wheel W being keyed to the frame and thus prevented from rotating, the motion of the train-arm will cause *w* to turn in the same direction and with the same velocity that it would have if fixed to a wheel, V, whose radius is D C, rolling inside a fixed wheel U whose radius is C O = 2 C D. By varying the distance C D, then, we in effect vary the actual, but not the relative, diameters of U and V, thus increasing the range of the instrument.

Now produce the link C G to L, making G L = G C; place another block at O in the slotted arm, and connect it with C L by the link L O, which will be parallel to G D and twice as long: and join D with the middle point of L O by a link D H, which will be parallel and equal to G L. This system of jointed links is for the purpose of facilitating the adjustment; if the outer block at O be secured anywhere in the slot, it is obvious that D will necessarily bisect C O.

The shank of the pen turns freely in a socket P carried by a bar which is secured by suitable means to the shaft of the wheel *w*, with proper provision for adjustment by varying the distance P D. Drawing through P and D the diameter I J of the circle V, it will be seen that the points I J, will travel in the right lines I C, J C, while P describes an ellipse as shown, to which P O is always normal, and the pen is controlled by the bridle rod as in Fig. 2.

The point P is here placed *within* the virtual rolling circle V, for the purpose of avoiding interference of the bar P D with the pin projecting downward at O to carry the bridle-rod, which would occur if P were placed outside that circle as in Fig. 1. In Fig. 4, then, the semi-major axis is equal to P I, and the semi-minor to P J; the diameter I J being in this case equal to the *sum* of the semi-axes, whereas the corresponding diameter A B in Fig. 1 is equal to their difference.

In all these devices, the pen is controlled by means of the normal; but the tangent may be employed instead. In Fig. 5, C is the center, A and B are the foci, of an ellipse to which T T is tangent at P. Draw B E perpendicular to the tangent, cutting T T in D and A P produced in E; and also the right lines B P, C D. Then because T T bisects the angle B P E, we have P E = P B, and D E = D B. Therefore A E = A P + P B = major axis, and since A B is bisected at C, it follows that C D is parallel to A E and equal to the semi-major axis.

In Fig. 6 is shown the skeleton of an elliptograph based upon this property, the details of which were very neatly elaborated some four years ago by Mr. C. P. Benns, at that time a student in the Stevens Institute of Technology. The equal and parallel rods C H, A G, turn respectively about the fixed centers C, A, their outer ends being connected by a rod G H parallel and equal to A C, forming a jointed parallelogram. It is to be understood that C is fixed in the frame of the instrument, at the center of the proposed ellipse, A C and G H, being capable of adjustment, so that A shall coincide with one of the foci. On A G slides a socket which can be clamped at any position; this is to be set so that A E = major axis. Another socket which slides on C H is to be set at D, making C D = semi-major axis. To this latter socket is pivoted at D a bar T T, to which is rigidly secured a bar D F perpendicular to T T; this arm D F slides through a socket which is pivoted at E to the socket clamped upon A G. The bar T T itself slides through another socket, which is pivoted at P to still another one which slides freely upon A G. Thus when in action, E moves in a circle about A, and D in a circle about C, while P traces the ellipse, to which T T, as shown in Fig. 5, is always tangent. Therefore the pen, whose marking edges are fixed to coincide with T T in direction, is so governed as always to make a smooth line, whatever the eccentricity of the curve.

The arm F D virtually rotates about the focus B, since its prolongation, as shown by the dotted line, always passes through that point. And by actually prolonging that arm, and allowing it to slide through a socket pivoted at the fixed point B, the link G H of the jointed parallelogram might be dispensed with, the whole action being determined by the rotations around A, B, and C. Probably that substitution would not improve the steadiness of the motion, nor be practically advantageous in any respect. But it may be of interest to note, that it would render the

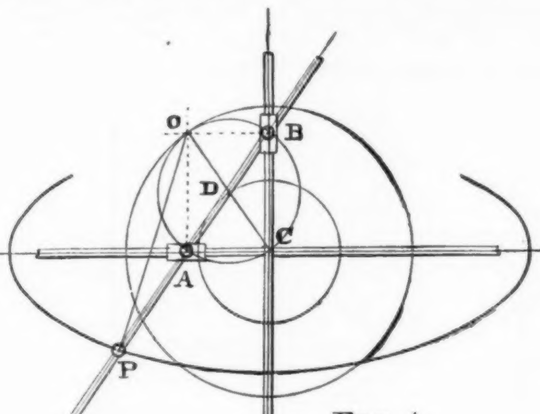


FIG. 1.

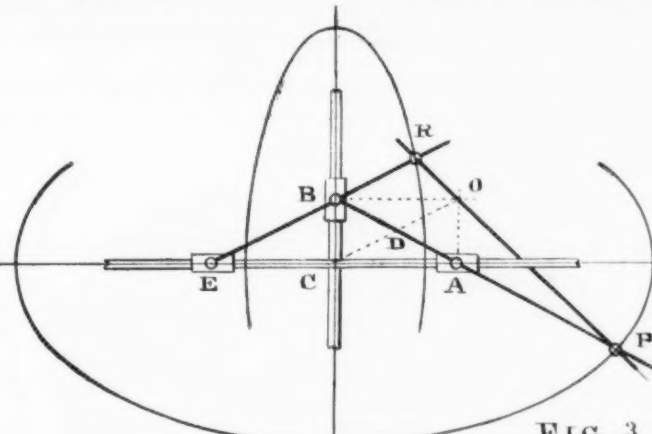


FIG. 3.

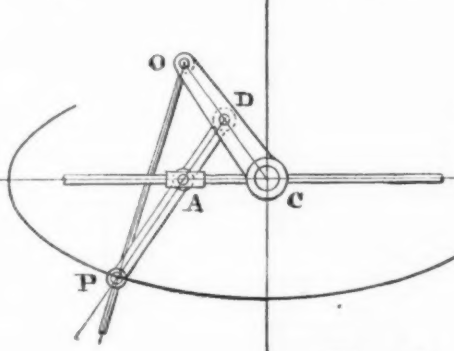


FIG. 2.

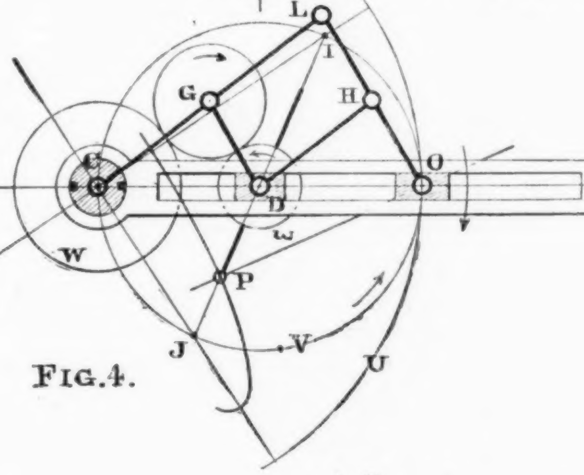


FIG. 4.

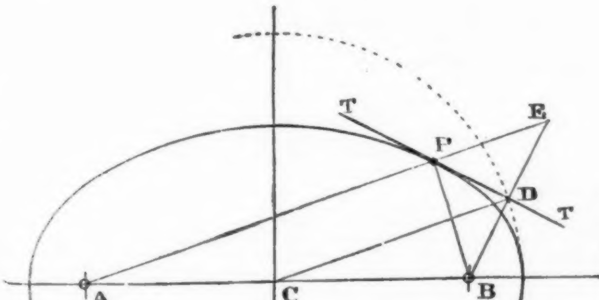


FIG. 5.

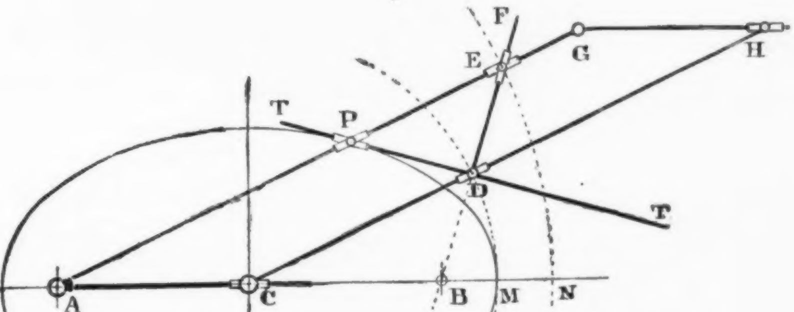


FIG. 6.

INSTRUMENTS FOR DRAWING CURVES—THE ELLIPSE.

construction substantially identical with that of the mechanical device for drawing the hyperbola, described in the first article of this series (SCIENTIFIC AMERICAN SUPPLEMENT, No. 530). And the principle is exactly the same as that of the instrument for drawing the parabola, shown in the SCIENTIFIC AMERICAN SUPPLEMENT, No. 585, as will be seen from Fig. 6; if we imagine C and A to be infinitely remote, the point B, remaining where it is, will then be the focus of a parabola. In that case the arcs M D, N E, will become right lines perpendicular to the axis, the former being the tangent at the vertex and the latter the directrix; and the radius A E, being now infinite, will become parallel to the axis. It is to be observed that in the case of the ellipse, the length of the arc N E is twice that of the arc M D, and this holding true at the limit, the result is that, as shown in the instrument referred to, the line B D F, perpendicular to the tangent, will still rotate about the focus of the parabola.

THE CITY HALL, PHILADELPHIA.

THE magnificent new City Hall, which has been in course of construction for twenty-one years, is now sufficiently near completion to accommodate many of the city and county offices, and some of the courts, all of which will eventually be removed to this noble building. The great pile of white marble, larger than any other single building on this continent, is surrounded by a grand avenue, 135 ft. wide on the eastern, western, and southern fronts, and 205 ft. wide on the northern front. The dimensions are 470 ft. from east to west and 486½ ft. from north to south. The structure contains 750 rooms, fitted with every convenience in heat, light, and ventilation, the whole being absolutely fireproof and indestructible. Its cost, thus far, has been about $15,000,000, exclusive of the site, which represents a value of at least $5,000,000 additional.

Several millions and several years will be required to complete the work. On the north front of the building rises the tallest tower in the world, surmounted by a heroic statue of William Penn, 36½ ft. in height. From the sidewalk to the crown of Penn's broad-brimmed hat the distance will be 547 ft. 3½ in.

The next highest building on earth is the Cologne Cathedral, 510 ft. The Washington Monument is 32½ in. higher, but cannot properly be classed as a building in the same sense as the City Hall. The latter will be 67 ft. higher than the Great Pyramid, 100 ft. higher than St. Peter's, Rome, and 187 ft. higher than St. Paul's, London, while it nearly doubles in altitude the Capitol at Washington.

The tower has now reached a height of 337 ft., and it is estimated that it will cost a round million dollars to finish it.

THE CITY HALL, PHILADELPHIA.

[FROM THE FORTNIGHTLY REVIEW.]

WHEN THE SUN MUST DIE.

IT seems to be worth while to collect together what may be said on the subject of the duration of life on the globe. It is a noteworthy fact that the possibility of the continued existence of the human race depends fundamentally upon the question of heat. If heat, or what is equivalent to heat, does not last, then man cannot last either. There is no shirking this plain truism.

Of course, it is obvious that the available heat generally comes from the sun. So far as the coal goes, we have already observed that, as it is limited in quantity, it can offer no perennial supply. Doubtless there is in the earth some quantity of other materials capable of oxidation, or of undergoing other chemical change; in the course of which, and as an incident of such change, heat is evolved. The amount of heat that can possibly arise from such sources is strictly limited. There is in the entire earth just a certain number of units of heat possible from such combinations, but after the combination has been effected there cannot be any more heat from this source.

Then as to the internal heat of the earth due to the incandescent state of its interior. Here, there is no doubt a large store of energy, but still it is of limited quantity, and it is also on the wane. This heat is occasionally copiously liberated by volcanoes, but ordinarily the transit of heat from the interior to the surface and its discharge from thence by radiation is a slow process. It is, however, sufficient for our present purpose to observe that, slow though the escape may be, it is incessantly going on. There is only a definite number of units of heat contained in the interior of the earth at this moment, and as they are gradually diminishing, and as there is no source from whence the loss can be replenished, there is here no supply of warmth that can be relied on permanently. It goes without saying that the welfare of the human race is necessarily connected with the continuance of the sun's beneficent action. If the sun ever ceases to shine, then must it be certain that there is a term beyond which human existence, or indeed organic existence of any type whatever, cannot any longer endure on earth.

But we have grounds for knowing as a certainty that the sun cannot escape from the destiny that sooner or later overtakes the spendthrift. In his interesting studies of this subject Prof. Langley gives a striking illustration of the rate at which the solar heat is being squandered at this moment. He remarks that the great coal fields of Pennsylvania contain enough of the precious mineral to supply the wants of the United States for a thousand years. If all that tremendous accumulation of fuel were to be extracted and burned in one vast conflagration, the total quantity of heat that would be produced would no doubt be stupendous, and yet, says this authority, who has taught us so much about the sun, all the heat developed by that terrific coal fire would not be equal to that which the sun pours forth in the thousandth part of each single second. When we reflect that this expenditure of heat has been going on not alone for the centuries during which the earth has been the abode of man, but also for those periods which we cannot estimate except by saying that they are doubtless millions of years during which there has been life on the globe, then indeed we begin to comprehend how vast must have been the capital of heat with which the sun started on its career.

And yet we feel certain that the incessant radiation from the sun must be producing a profound effect on its stores of energy. The only way of reconciling this with the total absence of evidence of the expected changes is to be found in the supposition that such is the mighty mass of the sun, such the prodigious supply of heat, or what is equivalent to heat, that it contains, that the grand transformation through which it is passing proceeds at a rate so slow that, during the ages accessible to our observations, the results achieved have been imperceptible. But the energy of the system is as surely declining as the energy of the clock declines as the weight runs down.

It was long a mystery how the sun was able to retain its heat so as continually to supply its prodigious rate of expenditure. The suppositions that would most naturally occur were shown to be utterly insufficient. We know that a great iron casting often takes many hours to grow cold after it has been drawn from the mould. If the casting be a sufficiently large one, the cooling will proceed so slowly that it will not get cold for days, because the tardiness of cooling increases with the dimensions of the body. It was not, perhaps, unnatural to suppose that as the sun was so vast the process of cooling would proceed with such extreme slowness that, notwithstanding the quantity of heat poured out every second, the annual amount of loss would be so small relatively to the whole store that the effect of that loss would be imperceptible in such periods as those over which our knowledge extends. This supposition, however plausible, is speedily demolished when brought to the test by which all such questions must be decided—the test of actual calculation. We can determine with all needful accuracy the store of heat that the sun would contain if regarded merely as a white hot solid globe. When we apply the known annual loss, we see at once that if the sun had merely the simple constitution here supposed, the annual expenditure would bear such a considerable proportion to the total supply that the effect of the loss would become speedily apparent. It is certain that the sun must under such circumstances fall some degrees in temperature each year. In a couple of thousand years the change in temperature would be sufficiently great to affect in the profoundest manner the supply of sunbeams. As, however, we know that for a couple of thousand years, or indeed for periods much longer still, there has been no perceptible decrease in the volume of solar radiations, we conclude that the great luminary cannot be regarded merely as a glowing solid globe dispensing its heat by radiation. There is another supposition as to the continuance of sun heat which must be mentioned, only, however, to be dismissed as quite incapable of offering any solution to the problem. As we generate heat here so largely by the combination of fuel, it has been sometimes thought that a similar process may be in progress on the sun. It has been supposed that elements capable and desirous of chemical union may exist in the sun in such profusion that by their entering into association a quantity of heat is liberated sufficient to account for the continuous dispersal by radiation. Here, again, the test must be applied which is decisive of such pretensions. It may certainly be the case that chemical actions of one kind or another are going on in the sun, and among them are doubtless some of such a character that they evolve heat. But we happen to know exactly how much heat can be evolved by the action of specified quantities of elementary bodies by whose

union heat is generated. It appears clear from the figures that chemical action is a wholly inadequate method of accounting for solar radiation. To take one instance, we may mention that if the sun had been a globe of white hot carbon, and if there had been a sufficient supply of oxygen to effect its combustion, the total heat generated by the entire mass would not supply the solar radiation for the period that has elapsed since the building of the Pyramids. It is, therefore, clear that the supposition that the sun is a burning globe, like the supposition of the sun as a cooling solid globe, is quite inadequate to explain the marvelous persistence with which, for countless ages, the orb of day has distributed its beams.

There is another supposition which, though not itself providing the explanation that we are searching for, still points so far in that direction that I have kept it till the last. It has been sometimes suggested that the dashing of meteoric matter into the sun from outside may afford the requisite supply of energy. It can, however, be shown that there are not enough meteors in existence to supply a sufficient quantity of heat to the sun to compensate the loss by radiation. The indraught of meteoric matter may indeed tend in some small degree to retard the ultimate cooling of the great luminary, but its effect is so small that we can quite afford to overlook it from the point of view that we are taking in this paper.

It is to Helmholtz that we are indebted for the true solution of the long-vexed problem. He has demonstrated, in the clearest manner, where the source of the sun's heat lies. It depends upon a cause that, at the first glance, would seem an insignificant one, but which the arithmetical test, that is so essential, at once raises to a position of the greatest importance. It is sufficiently obvious that the sun is in no sense to be regarded as a solid body. It seems very unlikely that there can be throughout its entire extent any portion which possesses the properties of a solid; certainly those exterior parts of the sun which are all that are accessible to our observation are anything but solid; they are vast volumes of luminous material floating in gases of a much less luminous nature. The openings between the clouds form the spots, while the mighty projections which leap from the sun's surface testify in the most emphatic manner to the gaseous or vaporous character of the outer parts of the great luminary. A gaseous globe like the sun, when it parts with its heat, observes laws of a very different type from those which a cooling solid follows. As the heat disappears by radiation, the body contracts; the gaseous object, however, decreases in general much more than a solid body would do for the same loss of heat. This is connected with a striking difference between the manner in which the two bodies change in temperature. The solid, as it loses heat, also loses temperature; the gas, on the other hand, does not necessarily lose temperature, even though it is losing heat. Indeed, it may happen that the very fact that the gaseous globe is losing heat may be the cause of its actually gaining in temperature, and becoming hotter. This seems a paradox at the first glance, but it will be found not to be so when due attention is paid to the different notions that belong to the words heat and temperature. The globe of gas unquestionably radiates heat and loses it, and the globe, in consequenceof that loss, shrinks to a smaller size. The heat, or what is equivalent to heat, that is left in the globe is exhibited in a body of reduced dimensions, and in that smaller body the heat shows to such advantage that the globe actually exhibits a temperature hotter than before the loss of heat took place. In the facts just mentioned we have an explanation of the sustained heat of the sun. Of course we cannot assume that in our calculations the sun is to be treated as if it were gaseous throughout its entire mass, but it approximates so largely to the gaseous state in the greater part of its bulk that we can feel no hesitation in adopting the belief that the true cause has been found. To justify the adequacy of this method of explaining the facts, I may mention the following result of a calculation. If the sun were to lose sufficient heat to enable it to shrink in its diameter by one ten-thousandth part of its present amount, the quantity of heat that would be available in consequence of this contraction would suffice to provide the entire radiation for a period of 2,000 years. Such a diminution of the sun's bulk would be altogether too small to be perceptible by the most refined measurements that we can make in the observatory. Hence we are able to understand how the prodigious radiation of the sun during all the centuries of history can be accounted for without any alterations in the dimensions of the great luminary having yet become appreciable.

But there is a boundary to the prospect of the continuance of the sun's radiation. Of course, as the loss of heat goes on the gaseous parts will turn into liquids, and as the process is still further protracted the liquids will transform into solids. Thus we look forward to a time when the radiation of the sun can be no longer conducted in conformity with the laws which dictate the loss of heat from a gaseous body. When this state is reached the sun may, no doubt, be an incandescent solid with a brilliance as great as is compatible with that condition, but the further loss of heat will then involve loss of temperature. At the present time the body may be so far gaseous that the temperature of the sun remains absolutely constant. It may even be the case that the temperature of the sun, notwithstanding the undoubted loss of heat, is absolutely rising. It is, however, incontrovertible that a certain maximum temperature having been reached (whether we have yet reached it or not we do not know), temperature will then necessarily decline. There is certainly no doubt whatever that the sun, which is now losing heat, even if not actually falling in temperature, must at some time begin to lose its temperature. Then of course its capacity for radiating heat will begin to abate. The heat received by the earth from the great center of our system must, of course, decline. There seems no escape from the conclusion that the continuous loss of solar heat must still go on, so that the sun will pass through the various stages of brilliant incandescence, of glowing redness, of dull redness, until it ultimately becomes a dark and non-luminous star. In this final state the sun will literally join the majority. Every analogy would teach us that the dark and non-luminous bodies in the universe are far more numerous than the brilliant suns. We can never see the dark objects; we can discern their presence only indirectly. All the stars that we can see are merely those bodies which at this epoch of their career happen to be so highly heated as to be luminous.

There is thus a distinct limit to man's existence on the earth, dictated by the ultimate exhaustion of the sun. It is, of course, a question of much interest for us to speculate on the probable duration of the sun's beams in sufficient abundance for the continued maintenance of life. Perhaps the most reliable determinations are those which have been made by Prof. Langley. They are based on his own experiments upon the intensity of solar radiation, conducted under circumstances that give them special value. I shall endeavor to give a summary of the interesting results at which he has arrived.

The utmost amount of heat that it would ever have been possible for the sun to contain would supply its radiation for 18,000,000 years at the present rate. Of course this does not assert that the sun, as a radiant body, may not be much older than the period named. We have already seen that the rate at which sunbeams are poured forth has gradually increased as the sun rose in temperature. In the early times the quantity of sunbeams dispensed was much less per annum than at present, and it is, therefore, quite possible that the figures may be so enlarged as to meet the requirements of any reasonable geological demand with regard to past duration of life on the earth.

It seems that the sun has dissipated about four-fifths of the energy with which it may have originally been endowed. At all events, it seems that, radiating energy at its present rate, the sun may hold out for 4,000,000 years, or for 5,000,000 years, but not for 10,000,000 years. Here, then, we discern in the remote future a limit to the duration of life on this globe. We have seen that it does not seem possible for any other source of heat to be available for replenishing the waning stores of the luminary. It may be that the heat was originally imparted to the sun as the result of some great collision between two bodies which were both dark before the collision took place, so that, in fact, the two dark masses coalesced into a vast nebula from which the whole of our system has been evolved. Of course, it is always conceivable that the sun may be reinvigorated by a repetition of a similar startling process. It is, however, hardly necessary to observe that so terrific a convulsion would be fatal to life in the solar system. Neither from the heavens above, nor from the earth beneath, does it seem possible to discover any rescue for the human race from the inevitable end. The race is as mortal as the individual, and, so far as we know, its span cannot under any circumstances be run out beyond a number of millions of years which can certainly be told on the fingers of both hands, and probably on the fingers of one.

ROBERT S. BALL.

NEW STATUE OF CHRISTOPHER COLUMBUS.

NEW STATUE OF CHRISTOPHER COLUMBUS.

WE give from *La Ilustracion*, Madrid, a drawing of a new statue of Christopher Columbus which is to crown the monument in the Plaza de la Paz. Its author is the accomplished artist, Don Rafael Atche. The statue is to stand at a height of 85 ft., and the artist has modeled it in colossal size, to the end that the height at which it is to be placed will not render it diminutive. The sculpture measures about 23 ft. high, and will be cast in three pieces by Vidal & Co., Madrid, who also have cast the statues of Fame which are to adorn the four faces of the monument.

[Continued from SUPPLEMENT, No. 851, page 13597.]

ALUMINUM: ITS MANUFACTURE AND USES FROM AN ENGINEERING STANDPOINT.*

By ALFRED E. HUNT, C.E., President of the Pittsburg Reduction Company.

THE properties of aluminum which will probably give it the greatest availability in the arts are:

1. Its relative lightness.
2. Its non-tarnishing quality as compared with many other metals; aluminum not being acted upon by sulphur fumes at all, and being very much more slowly oxidized by moist atmospheres than most of the metals.
3. Its extreme malleability.
4. Its easy casting qualities.
5. The influence of the metal in various alloys will give it advantages, some of which I will try to enumerate and call to your attention.
6. Its high tensile strength and elasticity when weight for weight of the metal is compared with other metals, and especially when alloyed with a small percentage of titanium, silver or copper and properly worked by being rolled or hammered or otherwise drawn down.
7. Its high specific heat and electrical and heat conductivity.

Unfortunately, aluminium is not, section for section, as has been widely claimed, comparatively a very strong metal. It is only about as strong under tensile strain, section for section, as cast iron, and has less than one-half the strength of wrought iron under ordinary conditions. Under compression, the metal, unfortunately, has a very low elastic limit, although its extreme ductility allows the metal to flow on itself so freely as to make it for special purposes a very safe metal to use in compression. I show a series of cylinders of one and one-half inch diameter, which have each had a compressive strain of 200,000 pounds applied to them, together with the result of a compression strain of 180,000 pounds upon similar cylinders of cast iron.

The same remark applies to transverse tests on aluminum. It is not a rigid metal at all, and bends under transverse strains very readily. I append a table of results which, from our experience, I believe will show about the average tensile and compressive tests of commercially pure aluminum, unannealed:

		Pounds.
Elasticity limit per square inch in tension	(castings).......	5,000
" "	(sheet)........	12,000
" "	(wire)...16,000 to	30,000
" "	(bars)	10,000
Ultimate strength per sq. in. in tension	(castings)......	15,000
" "	(sheet)	24,000
" "	(wire)...30,000 to	65,000
" "	(bars).	28,000
		Per cent.
Percentage of reduction of area in tension	(castings)........	10
" "	(sheet)...........	25
" "	(wire)............	40
" "	(bars)............	20
		Pounds
Elastic limit per square inch under compression in cylinders, with 'ength twice the diameter............		3,500
Ultimate strength per square inch under compression in cylinders, with length twice the diameter.........		12,000
The modulus of elasticity of cast aluminum is about...		11.000,000
" " " forged " "		15,000,000
" " resilience of cast " "		0·1600
" " " forged " "		0·2200

Under torsional stress in Thurston's torsional ma-

* From the Journal of the Franklin Institute.

chine, the metal has much lower modulus of rigidity than iron or steel; its maximum shearing stress in castings being about 12,000 and in forgings about 16,000, being about that of pure copper. The angle of torsion is about equal to that of the softest steel.

The following tables of tests are of results obtained since those published in the article on "The Properties of Aluminum," by Alfred E. Hunt, John W. Langley and Charles M. Hall, published in the *Transactions of the American Institute of Mining Engineers*, vol. xiii.

It will be noted that the tensile strength of aluminum wire runs up very considerably over that of the rolled metal. This is due to the peculiar property of aluminum to harden under work. The metal requires frequent annealing in rolling; and if it is to be drawn into wire with as little annealing as possible, the tensile strength is increased very considerably. This property of the metal is increased especially if the aluminum is alloyed with a small percentage of copper, titanium or silver.

It is perfectly feasible to produce a wire of aluminum alloyed with a small percentage of silver, titanium, or copper, which will have a tensile strength of 80,000 pounds to the square inch, and which will have, weight for weight with copper wire, an electrical conductivity of 170, that of copper being 100. When it is taken into consideration that the copper will only have a tensile strength at maximum of say 30,000 pounds per square inch, against 80,000 pounds strength of the aluminum-titanium alloy, and when the further fact that iron or soft steel wire has only a conductivity of seventeen in the same scale, and has a less, or at most only an equal, tensile strength per square inch with the aluminum-titanium alloy, a wide field for usefulness for electrical conductors seems opened for the metal, even at present, when the price of the wire of aluminum-titanium alloy will necessarily be considerably higher; but when such an alloy can be produced in fine wire at a price of say fifteen times that of the iron wire, pound for pound, then as the section can be reduced the aluminum-titanium alloy will be the cheapest as well as the most advantageous for electrical conductors.

Two things, however, should always be borne in mind in considering the applicability of aluminum for given purposes in the arts. The first is that the properties of the metal are very considerably changed as regards strength, tenacity, hardness, rigidity and color, by alloying it with small percentages of other metals—conditions that do not materially change the specific gravity of the metal. The second is the relative weight of aluminum; taking the tensile strength of aluminum in relation to its weight, it is in plates as strong as steel at 80,000 pounds per square inch ultimate strength and in cold drawn wire as strong as steel at 180,000 pounds ultimate.

The specific gravity of aluminum, of course, is one of its most striking properties; it varies from 2·56 to 2·70. The weight of a given bulk of aluminum being taken as one, wrought iron is 2·90 times as heavy; structural steel is 2·95 times; copper, 3·60 times; ordinary high brass, 3·45 times; nickel, 3·50 times; silver, 4 times; lead, 4·80 times; gold, 7·70 times; and platinum 8·60 times as heavy. Most woods that would be used for structural purposes are about one-third as heavy as aluminum.

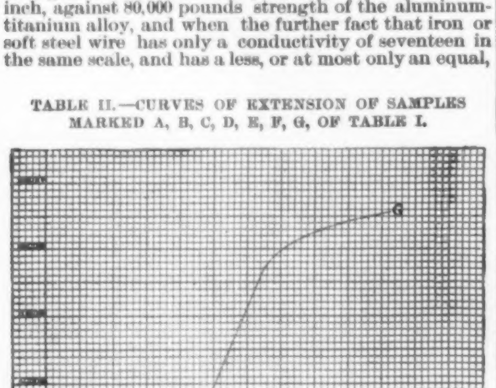
TABLE I.—TENSION TESTS.

	Elastic Limit. Pounds per Sq. In.	Tensile Strength. Pounds per Sq. In.	Reduction of Area. Per Cent.	Elongation in 8 Inches. Per Cent.	Modulus of Elasticity.	Modulus of Resilience.	Character of Fracture.	Remarks.
Cast aluminum rods ½ inch, diameter A.	—	15,336	4·70	3·9	11,000,000	—	Granular.	Very pure soft metal annealed.
" " 1⅛ " B.	2,168	11,849	2·50	2·25	10,084,000	0·2127	Granular.	" " "
" " 1⅛ " C.	2,016	11,870	0·40	3·50	8,338,631	0·2005	Granular.	" " "
" " ⅝ " D.	5,128	12,820	10·30	1·50	15,194,074	0·0721	Granular.	" " "
" " mean of above	3,029	13,011	4·40	2·78	11,270,268	0·1618	Granular.	" " "
Forged aluminum rods ½ inch, diameter E.	9,836	26,901	0·70	0·78	15,460,392	0·2602	Granular.	" " "
" " 1⅛ " F.	6,110	17,705	3·80	2·50	9,400,784	0·1834	Granular.	" " "
" " 6·10 " G.	—	20,400	10·00	2·34	—	—	Granular.	" " "
" " mean of above	7,983	21,270	4·80	1·15	12,430,580	0·2118	Granular.	" " "
Drawn aluminum wire, No. 16, B. & S. Gauge	19,430	65,300	14·30	7·10	19,700,000	—	Silky.	Cold drawn metal 98 per cent. pure.
" " No. 16, "	10,500	32,310	15·[illegible]	8·90	—	—	Silky.	" " " annealed.
Aluminum casting hardened with 3 per cent. copper,	6,132	15,640	8·66	—	—	—	Granular.	
" " drop forged,	9,220	18,310	5·30	3·30	—	—	Granular.	
" sheet, No. 20, B. & S. Gauge,	6,390	23,510	0·60	2·10	—	—	Silky.	Metal of 97¾ per cent. pure, remainder mostly silicon.
" " No. 10, "	9,680	29,630	4·10	1·90	—	—	Granular.	Metal cold rolled 98 per cent. pure.

TABLE III.—TORSION TESTS.

	Moment of Torsion. Inch Pounds.		Angle of Torsion. Degrees.		Extension of Outer Fibre.			Shearing Stress.			
	Elastic Limit.	Maximum Strength.	Elastic Limit.	Maximum Limit.	Elastic Limit.	Maximum Extension.	Final Extension.	Elastic Limit.	Maximum Stress.	Modulus of Rigidity.	Elastic Resilience.
Cast Aluminum 0·751 inches diameter,	—	1114·76	—	110°	—	·166	·1660	—	13,473	—	—
Forged " 0·751 "	666·40	1274·	1·56°	260°	·00003	·738	·9120	8163·	15,285	843,658	8·99
Cast " 0·980 "	—	2548·	—	72·5°	—	·0753	·0735	—	—	—	—
Forged " 0·980 "	1433·	2942·	5·0°	157·5°	·0003	·317	·4490	7802·	16,022	186,133	62·34
Cast " 0·625 "	—	478·	—	109·5°	—	·1601	·1601	—	10,133	—	—
Forged " 0·600 "	478·	755·	4·35°	37·5°	·00014	·048	·1490	10133·	16,593	416,318	18·15
Cast " 0·780 "	3036·	1115·	2·18°	30·25°	·00007	·0183	·0193	9015·	13,143	869,849	29·67
Forged " 0·780 "	319·	2894·	1·25°	18·75	·0·001	·359	·6550	3753·	14,089	481,594	3·99

TABLE II.—CURVES OF EXTENSION OF SAMPLES MARKED A, B, C, D, E, F, G, OF TABLE I.



The specific gravity of aluminum is 2·56 in ingots and 2·64 in forged bars.

A cubic inch of cast aluminum weighs 0·092 pound; of rolled sheet metal, 0·098 pound.

	Weight in pounds of one cubic foot.	Tensile strength per square inch.	Length of bar in feet able to support its own weight.
Cast iron	444	16,000	535
Ordinary gun bronze.	525	36,000	9,893
Wrought iron plates..	480	50,000	15,000
Aluminum plates	165	26,000	23,000
(cold rolled).	168	35,000	39,615
(cast)	160	15,000	13,231
(forged)	165	20,000	17,700

Wherever momentum is to be overcome, as in the reciprocal parts of many forms of machinery, aluminum can be advantageously used.

For valves, for structural purposes, and for machinery where lightness is a prime factor and where the wear due to the softness of the metal in bearings can be avoided by bushing, and its pliability can be overcome by properly designed sections and by using metal hardened by alloying and by cold rolling, drop forging, or otherwise stiffening it up, the metal can be used advantageously and deserves further consideration.

Aluminum does not oxidize seriously so as to interfere at all with the strength of thin sections of the metal, as does iron or steel; the thin film of oxide which covers the surfaces of the metal which have been long exposed to moist atmosphere seems to prevent its being further acted upon. But it does give a surface tarnish to the metal which cannot be rubbed off with the usual metal polishing compounds without interfering with the surface of the soft metal. This, however, can be removed by rubbing with a flannel rag which has been immersed in a two per cent. solution of hydrofluoric acid and then again rubbing up the polish with a rag saturated with carbon oil. Special aluminum polishes have been devised which work very efficiently. When properly cared for, polished surfaces can thus be kept bright for a remarkably long time.

As compared with most metals, pure aluminum, under ordinary circumstances, withstands the action of wind and weather exceedingly well; and many uses to which the metal is now being successfully applied are based upon this fact. The presence of silicon in aluminum materially detracts from its power to withstand corrosion due to atmospheric influences. Metal with four per cent. or five per cent. of silicon very soon collects a thick coating of oxide upon it, if severely exposed. The fact that pure aluminum is not severely acted upon by boiling water or by steam has led to its successful use as a packing or gasket in steam connections, where lead and similar metals have been rapidly cut out, as in parts of steam and water pumps and difficult steam joints.

Aluminum is not acted upon by carbonic acid or carbonic oxide, or sulphureted hydrogen, at any temperature less than 600° F., and these facts will undoubtedly lead to its application for many new purposes in the future.

Aluminum is found to withstand the action of organic secretions better even than silver, and for many forms of surgical instruments and apparatus, such as suture wires and tracheometer tubes, the metal is already receiving very wide use. Many surgeons are having their instrument cases made of aluminum, it having the advantage that they can safely be washed clean with antiseptic solutions. It may be well, however, to say here that perspiration in handling polished aluminum does tarnish the metal, and that aluminum, like other metals, cannot retain a high polish with frequent handling. The natural acid solvent for aluminum is hydrochloric acid. Solutions of the strong caustic alkalies, chlorine, bromine, iodine, and fluorine rapidly corrode aluminum. Ammonia gas has very little action on the metal, except to turn it a gray color. Strong aqua ammonia has a slight solvent action upon it.

I take pleasure in exhibiting two plates of about six inches square each, one of aluminum and one of copper, which have been nailed upon the wooden sides of a schooner that has made a trip from New York to the West Indies and back, and were immersed in the sea water together for four months. The sheets weighed one pound two and three-quarter ounces avoirdupois for the copper sheet and five and three-eighths ounces for the aluminum sheet; neither sheet lost an appreciable amount by the service. The original thickness of the sheets was 0·087 inch each, and now is 0·087 inch and 0·086 inch, for the aluminum and copper, respectively, showing that the copper sheet corroded the most under equal treatment. Unfortunately for the advantageous use of aluminum as a sheathing for ships, however, the barnacles seem to thrive on the aluminum sheet, a satisfactory evidence of the relative non-corrodibility of the metal, but not of its availability for certain marine purposes.

For structural purposes under water, where metals are required, aluminum seems to be especially adapted to replace the more easily corroded cast and wrought iron and steel now in general use for such purposes. For liners and shims upon masonry foundations, aluminum is well adapted, as it flows sufficiently to allow equal bearings on all parts, and is less easily cut out than lead, and much more durable than tinned iron sheets, which are now in general use under heavy structures of metal resting on metal shims on masonry.

Aluminum sheets will make a much more durable and satisfactory roofing than sheet copper, now generally used in valuable buildings.

Under heat the coefficient of linear expansion of three-eighths inch round aluminum rods of ninety-eight and one-half per cent. purity gave results as follows:

$$\left.\begin{array}{l}0\cdot00002295\\0\cdot00002289\\0\cdot0000206\\0\cdot0000230\end{array}\right\}\text{per degree Centigrade,}$$

between the freezing and boiling points of water; that of iron being 0·0000122, tin 0·0000217, copper 0·00001718. The coefficient being obtained in the usual way by dividing the difference in length of the test bars at two given different temperatures by the product of the original length of the bars times the difference in temperatures.

The specific heat of aluminum, according to the experiments of Prof. J. W. Richards, is 0·02143, water being taken as one.

The coefficient of thermal conductivity of aluminum obtained by the method of Wiederman and Franz, silver being taken as 100 and copper as 73·6, is 37·96 (unannealed aluminum); annealed aluminum, 38·87.

Aluminum stands fourth, being preceded only by silver, copper, and gold, as a conductor of heat as well as electricity. One yard of annealed aluminum wire of ninety-eight and one-half per cent. purity, 0·0325 inch diameter at 14° C., having 0·05484 of an ohm resistance; a yard of pure copper wire having a resistance of 0·0315 under like conditions. The electrical conductivity of a standard section of pure silver being taken at 100, an equal section of copper also at 100, pure gold at 78·0, an equal section of pure annealed aluminum has an electrical conductivity of about 54·20.

Pure zinc	29·90
High brass	21·50
Pure tin	15·45
Soft 0·10 carbon open hearth steel	12·00
Platinum	10·60
Lead	8·88
Nickel	7·89
Antimony	3·88

Authority, Lazare Wiler. Communication to the Societe Internationale des Electriciens.

This relatively high electrical conductivity when equal weights are taken will undoubtedly prove a factor of importance in developing electrical uses for aluminum.

The electrical conductivity of aluminum is increased fully five per cent. by carefully annealing even the ordinary soft wire, and with hard-drawn wire the conductivity is increased by annealing nearly ten per cent.

Pure aluminum has no polarity, and indeed the commercial metal in the market is practically non-magnetic.

Pure aluminum is very sonorous, and its tone seems to be improved by alloying with a small percentage of silver or titanium. For the sounding boards of musical instruments, aluminum has been proved to be well adapted.

Pure aluminum, when properly treated, is a very malleable and ductile metal. It can readily be rolled into sheets 0·0005 of an inch thick, or be beaten into leaf nearly as thin as gold leaf, or be drawn into the finest wire. Pure aluminum stands third in the order of malleability, being exceeded only by gold and silver; and in the order of ductility, seventh, being exceeded by gold, silver, platinum, iron, soft steel, and copper. Both malleability and ductility are greatly impaired by the presence of the two common impurities, silicon and iron.

Aluminum can be rolled or hammered cold, but the metal is most malleable at, and should be heated to, between 350° and 400° F., for rolling or breaking down from the ingot to the best advantage. Like silver and gold, aluminum has to be frequently annealed, as it hardens up remarkably upon working. Due to this phenomenon of hardening during rolling, forging, stamping, or drawing, the metal may be turned out very rigid in finished shape, so that it will answer excellently well for purposes where the annealed metal would be entirely too soft, or too weak, or lacking in rigidity to answer. Especially is this true with aluminum alloyed with a small percentage of titanium, copper, or silicon. It can be safely stated, as a general rule, that under similar conditions the purer the aluminum, the softer and less rigid it is.

Aluminum can be annealed by heating and allowing

to cool gradually; the best temperature is just below the red heat. Thin sections can be annealed by heating in boiling water.

Aluminum can be easily and readily welded by the apparatus of the Thomson Electric Welding Company.

Until very lately the lack of methods for successfully soldering aluminum was among the greatest drawbacks to its introduction for many purposes. Thanks to your townsman, Mr. Jos. Richards, we have a cheap solder that works satisfactorily. I take pleasure in exhibiting soldered samples and pieces of the solder. The trouble with any solder is to get it to flow, for not only has the natural disinclination of most solders to spread over aluminum to be overcome, but also, due to its very high heat conductivity, the heat of the solder is withdrawn with such rapidity as to cause the solder to "freeze" before flowing sufficiently. This difficulty has been overcome in most cases by the use of a very hot soldering iron. In the most difficult places, the use of crystals of chloride of silver has been found to aid the flow of the solder. This use of chloride of silver for this purpose is subject to the United States patent No. 375,875, of Messrs. Page & Anderson, of Waterbury, Conn.; their patent rights being for sale by W. H. Pierce, 37 Platt Building, Waterbury, Conn.

Sound castings of aluminum can be made in dry sand moulds or in metal chills. As an evidence of this, I take pleasure in exhibiting a tea kettle cast from the metal by the Auburn Hollow Ware Company, of Auburn, N. Y. It, however, requires some experience and expertness on the part of the founder to master the peculiarities of the metal, before perfectly sound castings can be uniformly made. The aluminum should not be heated very much beyond the melting point, otherwise it seems to absorb gases, which remain in the metal, preventing sound castings. In small quantities the metal can be best melted [in plumbago crucibles; but in large quantities it can be more economically melted in a reverberatory furnace with alumina or magnesia brick sides and alumina bottom. The furnace should have a tap hole for drawing off the liquid metal into carbon-lined ladles. In no case need the metal be covered with a flux to assist in the fusion or to form a covering of slag. In fact, owing to the metal's lightness, the presence of any flux will tend to unsoundness, due to particles of it becoming entangled in the castings, while impurities may perhaps be added to the metal by the action of the flux on the lining of the melting vessel. The shrinkage of seventeen sixty-fourths of an inch per foot, which aluminum has, is considerably more than that of brass, which is about three thirty-seconds of an inch per foot.

Undoubtedly, one of the greatest uses for aluminum in the arts will be in the form of alloys with other metals. Aluminum in proportions of a small percentage added to very many different metals gives valuable properties. Among these alloys is, of course, aluminum bronze. The alloys of from two and one-half per cent. to twelve per cent. aluminum with copper have so far achieved the greatest reputation. With the use of eight per cent. to twelve per cent. aluminum in copper we obtain one of the most dense, finest grained and strongest metals known, having remarkable ductility as compared with its tensile strength. A ten per cent. aluminum bronze can be made in forged bars with 100,000 pounds tensile strength, 60,000 pounds elastic limit, and with at least ten per cent. elongation in eight inches. An aluminum bronze can be made to fill a specification of even 130,000 pounds tensile strength and five per cent. elongation in eight inches. Such bronzes have a specific gravity of about 7·50, and are of a light yellow color. For cylinders to withstand high pressures, such bronze is probably the best metal yet known.

The five to seven per cent. aluminum bronzes have a specific gravity of 8·30 to 8 and are of a handsome yellow color, with a tensile strength of from 70,000 to 80,000 pounds per square inch and an elastic limit of 40,000 pounds per square inch. It will probably be bronzes of this latter character that will be most used, and the fact that such bronzes can be rolled and hammered at a red heat with proper precautions will add greatly to their use. Metal of this character can be worked in almost every way that steel can, and has for its advantages its greater strength and ductility and greater power to withstand corrosion, besides its fine color. With the price of aluminum reduced only a very little from the present rates, there is a strong probability of aluminum bronze replacing brass very largely.

A small percentage of aluminum added to Babbitt metal gives very superior results over the ordinary Babbitt metal. It has been found that the influence of the aluminum upon the ordinary tin-antimony-copper-Babbitt is to very considerably increase the durability and wearing properties of the alloy. Under compressive strain, aluminum-Babbitt shows to be a little softer than the ordinary Babbitt. A sample one and one-half inches diameter by one and one-half inch high began to lose shape at a pressure of 12,000 pounds. A similar sample of the same Babbitt metal without the addition of the aluminum (having a composition of 7·3 per cent. antimony, 3·7 per cent. copper, and 89 per cent. tin) did not begin to lose its shape until a compressive strain of 16,000 pounds had been applied. Both samples have stood about an equal strain of 35,000 pounds. In comparative tests of the ordinary Babbitt metal and the aluminum-Babbitt metal, the latter has given very satisfactory results. At the works of A. W. Cadman & Co., 63 Water Street, Pittsburg, a crank pin bearing of a thirty horse power engine with the ordinary Babbitt metal required resetting about every three days; and after inserting in the bearing aluminum-Babbitt strips of about a half-inch width upon the face, dovetailed in alternately in the brass bearing, the same bearings ran under similar work for two months without requiring any attention; and when examined at the end of two months the crank pin was found to have become very much smoother than it was before the aluminum-Babbitt had been inserted. Mr. Cadman recommends dovetailing in the strips of Babbitt, for the reason that it gives equal bearing all over the surface. Another advantage of this Babbitt is its extreme malleability. It can be hammered out to a thin edge without cracking, whereas the ordinary Babbitt is not at all malleable. An advantage of this is that for bearings, with aluminum, the Babbitt can be rolled into shape for inserting in the dovetailed recesses, which can be cut and drifted out at a very small expense, and the amount of Babbitt required is reduced to a minimum.

Aluminum is also being used very successfully in steel castings, and has added very considerably to the progress which has been made within the last two years in obtaining sound steel castings. A large number of steel casting companies are regularly using the metal aluminum in quantities of from one-half pound to several pounds of aluminum to the ton of steel. In the manufacture of ordinary steel ingots by the open hearth and Bessemer processes, it has lately been shown in the article on "Aluminum in Steel Ingots," by Prof. J. W. Langley, at the January, 1891, meeting of the American Institute of Mining Engineers, that the use of aluminum in small proportions (from one-third to three-fourths of a pound of aluminum to the ton of steel) has proved to be an economical success, preventing blowholes and unsound tops of ingots.

Alloys of aluminum with copper in proportion of from two per cent. to fifteen per cent. have been advantageously used to harden aluminum in cases where a more rigid metal is required than pure aluminum. Copper is one of the most common metals used at present to harden aluminum. A small percentage of copper decreases the shrinkage of the metal and gives alloys that are especially adapted for art castings. The remainder of the range, from fifteen per cent. copper up to over eighty-five per cent. gives crystalline and brittle alloys of no use in the arts; which are of a grayish white color, up to eighty per cent. copper, where the distinctly yellow color of the copper begins to show itself.

With the exception of lead, antimony and mercury, aluminum unites readily with all metals, and many useful alloys of aluminum with other metals have been discovered within the last few years, and I prophesy that many more will be found within the next few years. I consider this field as one of the most promising for investigation of any of the "aluminum problems." The useful alloys of aluminum so far discovered are all in two groups, the one of aluminum with not over fifteen per cent. of other metals, the other of metals containing not over fifteen per cent. of aluminum; in the one case, the other metals imparting hardness and other useful qualities to the aluminum, and in the other the aluminum giving useful qualities to the other metals.

The alloy of a small percentage of silver with aluminum, to harden, whiten, and strengthen the metal, gives a metal especially adaptable for many fine instruments, tools and for electrical apparatus, where the work upon the product and its convenience are of more consequence than the increased price due to the addition of the silver. The silver lowers the melting point of aluminum and gives a metal susceptible of taking a fine polish and making fine castings.

Titanium and chromium can be readily alloyed with aluminum according to methods devised and patented by Prof. John W. Langley. This will probably prove to be the most valuable means of hardening aluminum; a small percentage of titanium rendering the metal, under work, very rigid and yet elastic at the same time. Chromium is the best metal for hardening aluminum castings, the triple alloy being best adapted where a very hard and yet elastic material is required.

More or less useful alloys have been made of aluminum with bismuth, nickel, cadmium, magnesium, manganese and tin, these alloys all being harder than pure aluminum; but it is by combinations of these metals, with additions, perhaps, of copper, lead and antimony, that alloys of most value have so far been discovered. Some are additions of only one per cent. to two per cent. of aluminum.

The modifications of pewter, britannia, white metal, delta metal, and the like, with additions of aluminum, have shown very useful qualities and will add very considerably to the demand for aluminum in the near future.

The following alloys have recently been found useful: Nickel aluminum, composed of twenty parts nickel and eight parts aluminum, used for decorative purposes; rosine, composed of forty parts nickel, ten parts silver, thirty parts aluminum, and twenty parts tin, for jewelers' work; sun bronze, composed of sixty parts cobalt (or forty parts cobalt), ten parts aluminum, forty (or thirty) parts copper; metalline, composed of thirty five parts cobalt, twenty-five parts aluminum, ten parts iron, and thirty parts copper.

Besides these, Prof. Emmens, the well known inventor of emmensite explosives, has great hopes for an alloy of aluminum bronze and nickel for a gun metal.

Prof. Roberts-Austen has discovered a beautiful alloy, containing twenty-two per cent. aluminum and seventy-eight per cent. gold, having a rich purple color with ruby tints.

The addition of from five per cent. to fifteen per cent. aluminum to type metal composed of twenty-five per cent. antimony and seventy-five per cent. lead, makes a metal giving sharper castings and a much more durable type.

To ordinary brass, the addition of aluminum gives superior strength and better anti-corrosive qualities.

Some very marked and valuable qualities have been discovered in the use of aluminum and zinc for various purposes.

A mixture of aluminum with zinc is made by the Delaware Metal Refinery, of Philadelphia, which has proved very useful in the galvanizing bath; adding one pound of the aluminized zinc alloy to each ton of spelter contained in the bath, and one pound of the alloy additional for each 1,000 pounds of new spelter put into the bath. The effects are to make the spelter more fluid, coating smoothly twenty per cent. more surface than ordinary spelter, with a surface that is brighter, more malleable and will double-seam much better than ordinary galvanized iron. The use of aluminized zinc for this purpose is patented by Jos. Richards, of Philadelphia.

The aluminized zinc has also been added to good advantage as an addition to ordinary brass mixtures; about one per cent. to the weight of the brass mixture of aluminized zinc being used, plunged with a pair of tongs under the surface of the metal, where it is stirred with a rod. The surface of the brass mixture is then skimmed, and after waiting about half a minute, until the bubbles of disengaged gas cease, poured as usual. The effects are to make sounder castings, increase the strength, and give a finer color to the metal, which will resist oxidation much longer than ordinary brass. Should the amount of iron in the brass mixture be high, as large an amount as two per cent. of aluminized zinc can be added to liquefy the iron. The use of aluminized zinc for brass alloys gives a heavier yield of metal than without its use; and the Delaware Metal Refinery people claim that the increased yield and sounder castings produced will much more than pay the slightly increased cost of the brass mixture by the addition of the aluminized zinc.

Aluminum has been successfully used to replace lithographic stone.

Powdered aluminum mixed with chlorate of potash is used to give a photographic flash light, which gives much less smoke than the magnesium compounds used.

The Tacony Iron Metal Company, another well-known Philadelphia concern, has successfully produced an aluminum coating for iron, which undoubtedly will have considerable use in the future.

Samples of their work I take pleasure in showing you this evening.

To the inventors who shall produce good methods of nickel, silver and gold plating aluminum, so that it can take the place of German and nickel silver, a rich reward is in waiting.

I have endeavored in the latter portion of this lecture to indicate a few of the uses that have already been established, and the openings that seem most prominent to my own observation of the use of aluminum. Undoubtedly, there are many other fields yet waiting for the metal which will yield rich returns to the successful investigator; and I close this lecture by again reiterating the prophecy that the financially most successful solution of the aluminum problems of the future "will be in the ways of utilizing the metal in the arts, rather than in devising more economical methods of manufacture."

BASIC SLAG FOR FERTILIZING.*

By Mr. W. H. MORRIS.

I HAVE been asked by our president to present a paper on the slag from the basic Bessemer process as prepared for fertilizing. As Mr. W. B. Phillips, in May, 1888, presented to the Birmingham meeting an able paper on this subject as developed up to that time, there seems little for me to add, and perhaps our experience can be well expressed by the homely proverb, "The proof of the pudding is in the eating." As the Pottstown Iron Company is the only party manufacturing this product in this country, it may be interesting to you to have the writer's personal experience in the use of it.

I have been using this material for some years on my lawn and garden, and have found it better than anything I have ever had, and am sure that any of you who could see the green grass during last month as bright as in early fall wherever the ground was bare from snow would be forced to acknowledge the advantages of this soil enricher. The grass on my lawn, as well as around our office, is green the whole winter, and at our steel works we have raised very good sod by the use of this phosphate, where without it we were unable to get the grass to grow either from seed or when repeatedly sodded. The same applies to garden truck; when the soil was first broken up, a good crop of vegetables was easily raised. My own gardener has had several premiums from Philadelphia seedsmen, notably last year, the first premium for sugar corn raised early in July, being the first sample sent them.

Our method is to grind the slag very finely, so that at least 60 per cent. of it will go through a screen of 22,000 meshes and 90 per cent. through a screen of 10,000 meshes to the inch, and in this seems to lie the main feature of its success. We have had several wonderful reports from various sections. Among others, where it has doubled the crop of wheat to the acre, and also in fruit-growing sections it has done well. Some claim that it will kill the curculio, the enemy of plum trees, and it has done well in Florida in competition with fish phosphates. The very fine powder will also destroy the bugs that infest the rose bushes and small fruits, and potato bugs are driven away by it. This, indeed, is one great merit for it, as there are no seeds or eggs of an animal character to be transmitted to the soil, it having been manufactured at a heat of nearly 3,000°.

We can fairly claim that there is more of this phosphate used than of any other brand, as the product of all the Continental steel works is absorbed, as well as those in England. It was some years before the English (who are slow to adopt a new thing) were willing to use it, and one of the managers of a well known English basic works expressed himself as considering it a national calamity that his slag was taken by the Germans. Since then, however, it has been absorbed at home, and I sincerely trust our own people will soon learn to realize the value of it. We are about putting in a mill for grinding it, and hope to have a constantly increasing demand. Our phosphoric acid runs over 20 per cent.; sometimes as high as 25, and at the price we sell it, it certainly is the cheapest phosphate in the world.

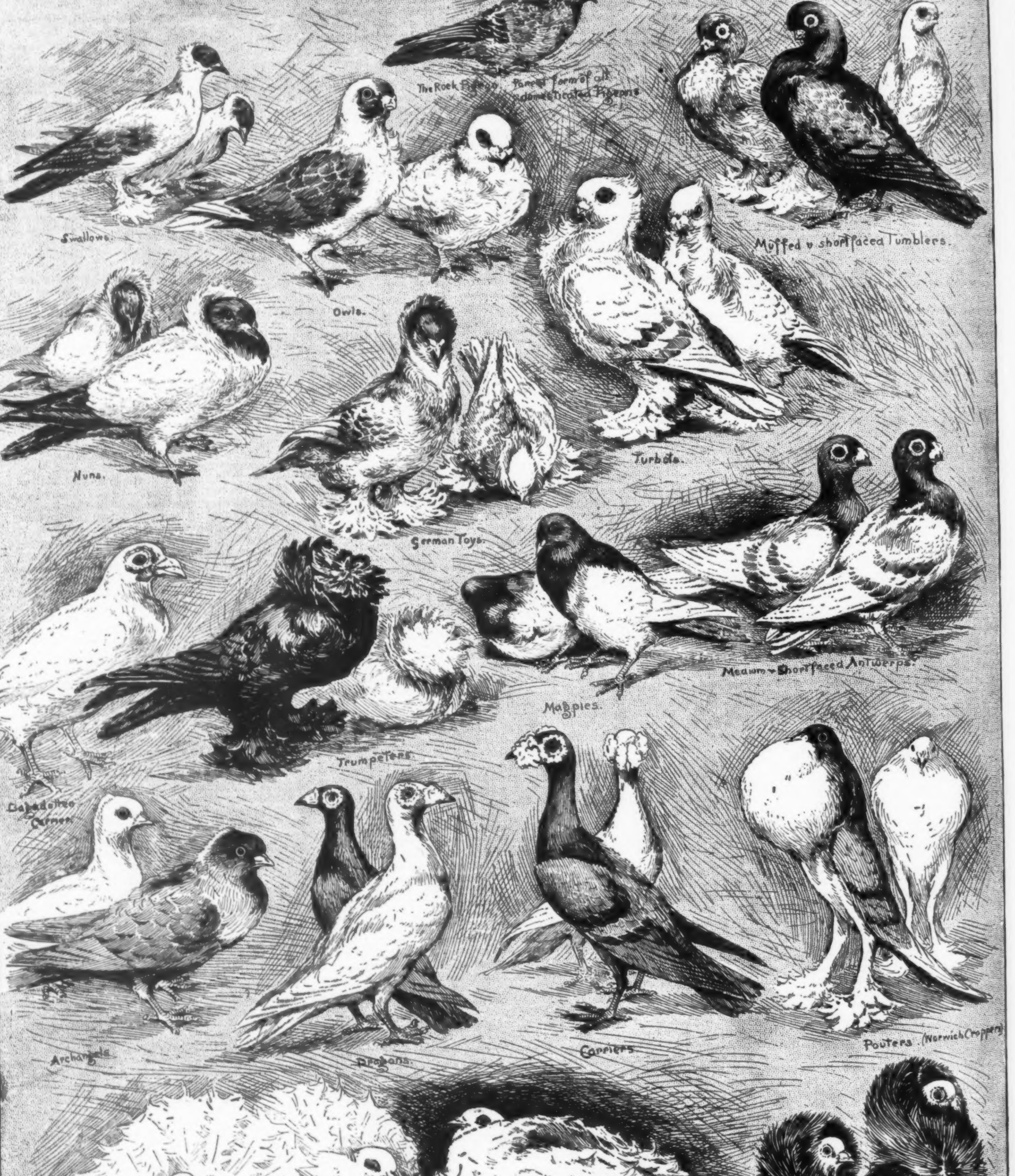
In Germany it has been found by practical experiment that the whole of the phosphoric acid is available, though for chemical reasons it does not respond to the same tests as the ordinary acid phosphate. The use of from 300 to 700 pounds to the acre is desirable, and it should be put into the soil at the proper depth. The full effect will not be shown the first year, but its beneficial influence will last through the second and third seasons, and by constantly applying, its value to the soil is regularly increased. Along with suitable manure to furnish the ammonia or with kainite to furnish some potash, it leaves nothing to be desired in the way of a model fertilizer.

Up to the present time between 4,000,000 and 5,000,000 tons have been sold. Our slag is a by-product from the basic Bessemer converter, but, unfortunately, the slag from the open hearth furnace is not nearly so rich in phosphoric acid, and consequently not so well adapted for fertilizing purposes. Dr. Wyatt estimates the phosphoric acid withdrawn yearly from the soil in the United States at nearly 5,000,000 tons.

* Paper read at the Baltimore meeting of the American Institute of Mining Engineers.

PIGEONS.

To those who have not considered the subject from a scientific point of view, it would appear almost incredible that all the numerous varieties of fancy pigeons, varying as much as they do in size, form, and color, should be descended from one wild original; yet, if one fact more clearly than another is made out in the history of our domestic animals, it is that the common blue rock pigeon, a native of the most inaccessible part of our coasts, is the progenitor of every species of fancy pigeon. The late Mr. Charles Darwin, in his large work on variation in animals and plants, fully demonstrated the fact that no other bird could have had any share in the origin of our domestic pigeon, and he showed by a series of experiments, in which I had the pleasure of assisting him, that by mating together the most extreme varieties, however dissimilar



SOME VARIETIES OF THE MODERN PIGEON.

in form and color, they would, after a few generations, revert more or less completely to their ancestral type, and show the blue color and black-barred wings of the blue rock.

My acquaintance with Mr. Darwin commenced at a pigeon show, held many years since in the great room at Freemasons' Hall, when Mr. Yarrell, the well known ornithologist, who had known me as a boy, introduced me to a stranger, saying: "Oh, Mr. Darwin, here's Tegetmeier; he will tell you what you want to know." Our introduction resulted in an acquaintance which endured during the lifetime of the great naturalist, who availed himself of the very considerable collection of specimens that I had made, illustrative of the variations that occur in domestic birds.

The rock dove, the *Columba livia* of naturalists, is a bird that is very generally distributed over a great part of the world; in Europe it is usually found inhabiting the coasts, where it can find the shelter of deep caves; in Palestine it is abundant on the coast; in North Africa it is commonly found; it also occurs in the Azores, Madeira, St. Helena, and other African islands; in Asia, it is found in Persia and India in large flocks, in holes in wells and large buildings. In Ceylon it is so numerous that there is an island called Pigeon Island.

There is little doubt of the identity of the species that inhabits these different localities, although there are slight variations in color, the Asiatic species being without the white on the back which distinguishes our European race. This wild bird is one of the few animals that admit of being domesticated or attached to the homes of men. Many wild animals can be tamed, but their offspring revert again to a wild condition; some few, on the other hand, become attached to man, and remain with him as domesticated animals.

Of these, the rock dove, or pigeon, is one of the most remarkable. As it has been readily domesticated, from the influence of the new surroundings, and from the care of man in breeding from any special variation that might have made its appearance, a number of varieties have been produced. Many of these are shown in our drawing.

The English fanciers, up to a very recent period, essayed to breed pigeons with marked difference in form, and they devoted their attention chiefly to what they termed high class varieties. Of these, the principal were short-faced tumblers, fancy carriers, and pouters.

The aim in the first breed was to produce an exceedingly diminutive bird with a very short beak, globular head, and a peculiar arrangement of the colors, which, in the choicest specimens, termed almond tumblers, were chiefly black and yellow.

In the breed known as fancy carrier, size, on the other hand, was desired, with great length of beak, length of neck, and length of limb; while the ring of white skin which surrounds the eyes and that which covers the nostrils were enormously developed, so as to produce what are termed the wattles of the carrier.

In the pouter, on the other hand, another development was aimed at. The pigeon naturally has a tendency to blow out the upper part of the gullet and the crop, inflating them with air as it coos to its mate. This tendency was seized upon by the fancier, who bred from the pigeons that showed this to the greatest extent, and so gradually succeeded in producing a breed in which the crop could be inflated so as to equal in size the whole of the rest of the body, and in this way was produced the pouter, or cropper.

It is a remarkable illustration of the variable condition of animal structures that out of the same wild original can be produced the long, thin, narrow-necked carrier and the pouter with its crop double the girth of its body. In both these breeds the limbs and feathers are long. This depends upon a fact that was demonstrated by Darwin, that there is a co-relation between the lengths of the different parts, and that it would be impracticable to breed a bird with a long neck and short limbs, or the converse.

Until pigeon keeping became, I may say, fashionable, the tumblers, the carriers, and the pouters were the most valued breeds of the British fancier; all the other varieties at that time were included in the somewhat contemptuous term of "toys." About fifty years ago several German breeds came to the front. These were more remarkable for the distribution in the colors in the plumage. Some, like those now termed "magpies," had colored bodies and white wings; others, like those now known as "swallows," had dark wings and light bodies. The "nuns" had dark heads covered with a turned crown. Then there were numerous birds known as German "toys," in which all kinds of patterns were produced by careful breeding. Every country, in fact, had its own modifications, requiring careful breeding to produce.

From Russia came birds called "trumpeters," from the sonorous character of their coo, distinguished by tufts of feathers on their crowns, so large as entirely to conceal the head, the eyes, and the beak, and also characterized by the legs and feet being covered with feathers.

As in many other cases, the geographical names given to birds were incorrect; there is a breed with a wonderful metallic sheen upon the feathers, which, absurdly enough, are called "Archangels," although there is no doubt they did not come from that locality. In fact, when geographical names are given to animals, it usually happens that the name selected is that of the place whence they were last brought; hence the absurd errors which usually characterize the names of races. Our Cochin China fowls do not come from Cochin, but from Shanghai, a place hundreds of miles away. Our little black ducks have received three names—Buenos Ayres, East Indian, and Labrador—a safe proof, if any were wanted, of the absurdity of geographical names as applied to animals, the truth being that they are merely varieties of our own wild duck.

In India the blue rock has been domesticated and carefully bred for thousands of years, and some very remarkable products have been the result of the care exercised in selection by the Oriental fancier. Some of the best of our fantails—the breed in which the number of feathers in the tail is increased to thirty or even forty—came from India; and to show the care which has been bestowed upon the bird there, I may state that there are varieties in which the two sides of the bird are of different colors.

In North Africa a very remarkable breed exists, termed the booz pigeon, characterized by its extremely small size, excessively short beak and round head; these are now known in England under the title of African owls. Previous to their introduction, a breed termed owls, or the owl pigeon, had existed in England; it was so called from the shortness of its beak, bearing some resemblance to the bird from which its name is derived. A breed that is very much like the owl is known as the turbit, which, even as late as fifty years ago, had a totally different form, being bred with a flat skull, and termed frog-headed. Fashion, however, has altered, and the modern turbit has assumed the short head and short beak which characterizes the owl. The same singular formation has also been introduced into the breed which in this country is called the Antwerp, a bird almost unknown in the city whence it takes its name.

Some varieties of pigeons are valued for the strange distribution and arrangement of the feathers. Among the most remarkable of these are the Jacobins, in which the feathers of the sides and back of the neck form a kind of hood, which, when the bird is at rest, almost entirely conceals the head; the origin of the name here is evident as having been suggested by the hood or cowl of a Jacobin monk.

The instinct of the pigeon to return to its home is very remarkable. It exists in the wild bird, or blue rock, and has, by careful selection, been greatly developed and even increased in certain domesticated breeds. But the varieties that are now termed carriers by the fanciers are not worthy of the title; they are mere fancy breeds, bred for show points and exhibition purposes, the most valuable specimens never being trusted out of the aviaries in which they are reared. The true messenger pigeons are now termed "homers," or, in Belgium, where the breed originated, *voyageur* pigeons. These are not reared to be any special color, but are selected solely from their powers of flight and their ability to return home long distances.

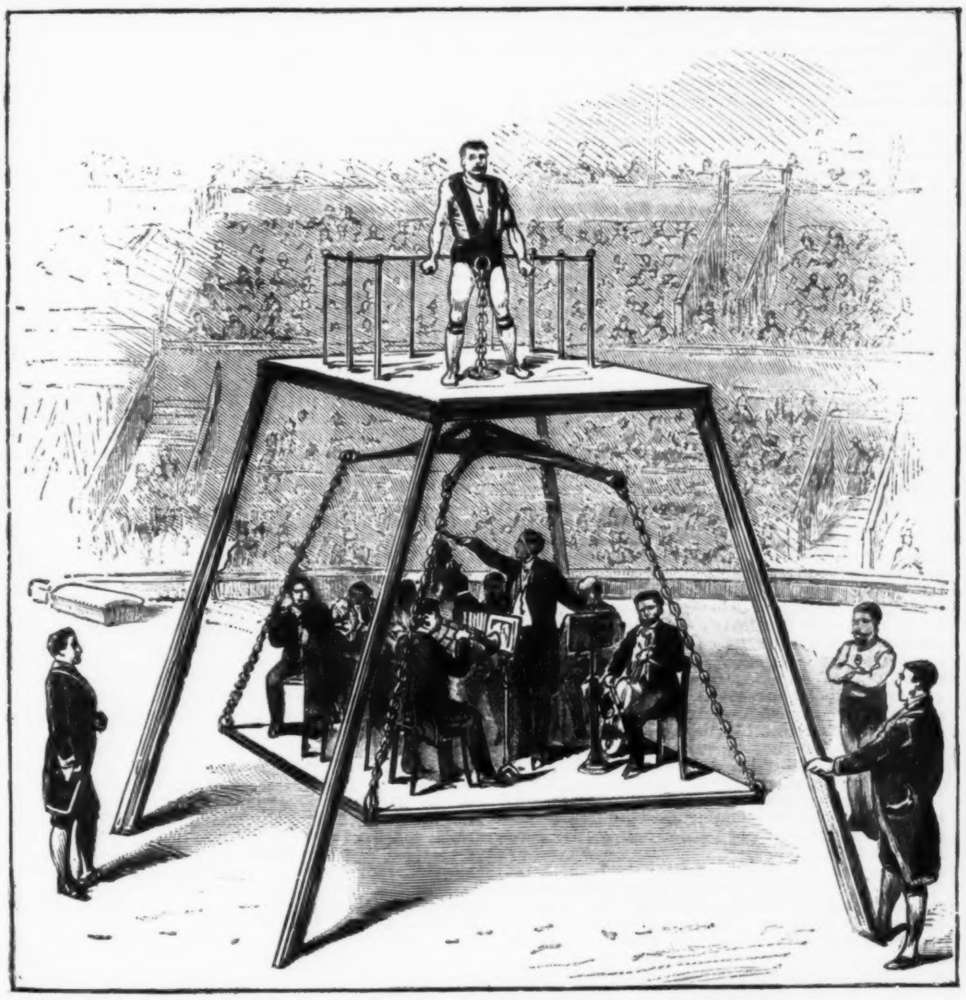
The process of selection is one of a ruthless character; the young birds are trained by gradually increasing distances up to as far as a hundred and fifty or two hundred miles during their first year, when those that are not good homers are lost, and the best only return home and propagate their species. In this way a race of birds has been obtained that can be depended upon for returning from immense distances. Flights have taken place from Rome to Brussels, and races are now flown from France to England.

The utility of the homing pigeons during the siege of Paris in the Franco-German war is well known. The birds were sent out in balloons, and carried intelligence back to the city, in spite of all the efforts of the besiegers to intercept them. This performance demonstrated the utility of homing pigeons during war, and the governments of France, Germany, and Italy have establishments of homers that will convey messages back to the fortress or place where their services are required.—*W. B. Tegetmeier, in the Illustrated London News.*

OXYGEN is a gas whose presence is necessary before the phenomenon of burning can take place, and hydrogen is a gas that burns with a pale blue flame, and yet the combination of these two gases forms water, which is the opposing element of fire.

THE ATHLETE RASSO.

THE accompanying cut, for which we are indebted to the *Illustrirte Zeitung*, represents the latest feat of the athlete Rasso, as performed at Renz's circus, in Berlin. Rasso bears every mark, so our contemporary says, of a real Hercules, and appears to be perfectly able to perform at least some of the renowned labors of this son of Zeus. The "labor" illustrated here is the lifting of an entire orchestra of twelve men, without the aid of magnetism or a "double floor." The length of time that Rasso is capable of sustaining this load has not yet been ascertained, as the patience of the audience has always given out sooner than the strength of the performer.



RASSO LIFTING AN ORCHESTRA OF TWELVE MEN.

[Continued from SUPPLEMENT, No. 853, p. 13635.]

PERU: ITS COMMERCE AND RESOURCES.*

By F. A. PEZET.

OF the trade of Peru through the Amazon very little is known in this country, for the simple reason that all the Peruvian products exported, specially rubber, sarsaparilla, ivory nuts, tobacco and copaiba, are generally classified among the exports from Brazil. The steamers which navigate the River Amazon and its principal affluents are all Brazilian, and at the Brazilian port of Para these exports are transferred to the larger steamers, which cross the Atlantic and convey them to Europe. In view of this, the Peruvian government have been authorized to offer a subsidy of $12,000 per annum to any steamship company which would undertake to run a regular line of steamers between the Peruvian rivers and the European ports.

As an item to any who may wish to study such a scheme, I will point out that the annual exportations from Iquitos amount to about 1,000,000 kilogrammes, while the value of the imports represent about 1,000,000 soles silver. Besides the rubber trade, there is every facility for the carrying on of a large business in timber and cabinet woods. And from what I learn from this region, I consider that the erection of proper and modern sawing mills would prove a highly profitable venture.

I trust that I have been able to prove to you that immigration on a large scale into the interior of Peru would be the means of opening up a very rich country. That this is commercially practicable and profitable there is not the least doubt, as the products indigenous to the region, and those which can be cultivated, are of such value, and of everyday increasing demand in the European markets, as to insure the success of the enterprise: while the mineral wealth is next to inexhaustible, and the pasture lands so extensive that any amount of cattle and domestic animals may be raised. I take it that you are all aware that, since the conversion of the old Peruvian external debt, the Peruvian Corporation, which was formed in order to take over the several concessions which Peru made to the bond holders, has sent several commissions to Peru, with a view of studying the agricultural resources of the country, for the purpose of establishing European settlements or colonies on the large tracts of land which have been ceded to them by the Peruvian government.

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* From the Journal of the Society of Arts, London.

Some of these commissions have now returned to England, and reported upon the country they have visited; and I am glad to see that they, more or less, indorse all my views on Peru as a field for enterprise. It is their opinion that the country is admirably suited for European immigration; and Mr. Clark, of the Royal Botanical Gardens, of Ceylon, on this subject says: "With a climate of such salubrity and adaptability to a European settlement; a soil of exceptionable fertility; an immunity from most of the parasitical plant pests; the tropical products found, with an adaptability to the introduction of other economic plants, which have proved so important to the development of other countries; together with the opening up of the country by means of improved transit, I have every confidence in the future prosperity of tropical Peru." It is, therefore, to this region that the European should go; and, by developing this part of the country, he would carry prosperity to the country at large. The railways already constructed, those in construction, as likewise those under survey, will all help to attain this end. These lines will place the Montana regions and their great arable lands in direct communication with the mining centers and with the coast. The interchange of products will give life to many new industries; population will be on the increase; fields of cultivation will extend; and by the waterways of eastern Peru, and by the Pacific, from its western shore, will be brought to Europe the great and varied products of that country, whose name during centuries has been a by-word for riches. But while, in bygone days, such a name only referred to the mineral kingdom, in the near future it shall also refer to the agricultural wealth, which, above everything else, constitutes the life of a nation—a wealth on which it can well repose, and, by so doing, dedicate its newly acquired energies to the further development of its other many resources.

I am not too sanguine by nature, and have been more of a pessimist than an optimist as a rule, in judgments and calculations, but I must confess that within the last two years I have grown more confident of my country's future; and I look upon you, the English nation, as the restorers of our former prosperity. Notwithstanding our financial default, you still come to our succor, and tend us a helping hand in the moment of need, and with that great energy so characteristic of your race, and which has expanded the limits of this little island until nothing can compare with it on the face of the globe, you now carry the standard of commerce and enterprise into the very heart of the old Inca empire, thereby serving the aims of civilization.

Well, you may be certain that we all feel quite grateful for this, and that it is our desire to help you in the carrying out of such a grandiose enterprise.

In the foregoing paragraph I say that we mean to be grateful, and that it is our desire to help the British public in carrying out their schemes with respect to the development of our country. In order to do this, the government have passed through Congress many most beneficial laws for the promotion of mining and agricultural pursuits. Education, which I may consider as the most powerful auxiliary of progress, and the main lever for raising a nation's social standard, meets with every support at the hands of the present administration. To-day, in Peru, besides the government, municipal and private schools, which are kept up throughout the whole country, there are special establishments supported by the government, where people of both sexes are taught some craft or other; schools of arts and sciences are being organized in different parts of the territory, and as I have already mentioned, there are good mining and engineering colleges, and schools for *capatazes*, overseers. A central agricultural college is already under consideration, and it is intended that in the agricultural districts special schools for the promotion of agricultural knowledge shall be established.

Import duties on machinery for agricultural, industrial, or mining purposes have been abolished; tools and implements for the same purposes are free, and so are many of the principal articles which serve for the promotion of industry.

Roads and means of communication are being established in different districts, so as to bring the far-off regions into closer and easier contact with the commercial or industrial centers. Telegraphic communication is fast extending throughout the country, and the navigation of the rivers of the interior is receiving the special attention of the government. Already the road from Tarma to the tropical forests of Chanchamayo places Lima within 36 hours of that rich portion of our territory. While the roads to La Merced, San Luis de Shuaro, and to the banks of the Pichis and Paucartambo, bring the Montana within easy access of Lima, and open an interoceanic communication from the Atlantic through the Amazon and its affluents, and overland to the Pacific.

Nearly all the railways of Peru are in the hands of the Peruvian Corporation, Limited, and the extension work on some of the more important lines is being carried on with great energy.

The economical condition of the country is progressing, slowly but surely, as a glance at these figures will prove. In 1888 the revenue derived from customs duties amounted to \$4,361,304.37, in 1889 to \$4,748,790.32, in 1890 to \$5,698,906.38, an increase of \$950,116.00 over 1889, and \$1,337,602.10 over 1888. The totals for last year are not yet to hand, but by comparison with the first six months of 1890 they show again a decided improvement for 1891. Other sources of revenue, such as taxes, post and telegraphs, stamped paper, etc., have also been on the increase. The estimates for the current year of 1892 show a revenue of \$7,103,887.64 and \$6,012,617.10 for expenditure, leaving \$1,091,806.04 to meet possible contingencies and a paper superavit of \$708.84. The estimates do not include the special revenues applied to special services, such as are derived from the leasing of the tobacco, opium, and alcohol monopolies, the mining royalties, and all municipal duties and contributions, all of which represent over \$500,000. Peru has to-day no external debt, her internal indebtedness amounting to about £500,000.

The banking system of Peru is carried on by the Banco del Callao, which has branch offices in several of the principal towns, the London Bank of Mexico and South America, and the Banco Italiano. There is no paper currency at present in the country, the silver sol, the value of which fluctuates according to rate of exchange and to the price of silver, being the standard coin of the country. It is a large piece of silver of the size of a double florin. The Banco del Callao issues a sort of "token" to bearer which circulates freely in the country.

I think that Peru requires a privileged bank of issue with a special charter, on the lines of that of the Bank of England, and I am confident that if a group of English bankers of repute were to make an offer to the government to establish such a bank, the thing would be immediately taken up and studied in Peru, as every one feels the necessity of such an establishment; more especially the agriculturists and miners, who are in sore need of capital in order to increase their productions. It is true that the banks, specially the Banco del Callao, do advance money on mortgages of real estate; but this is done at a high rate of interest, and for comparatively small sums. The Lima Mint, which is as fine a one as is found in South America, during 1891 turned 1,466 silver bars (the production of native mines), weighing 73,469,230 kilogrammes, into coin, the value of which was \$3,100,201.67 in Peruvian currency, about half a million sterling.

Peru being a producing country, and its principal and staple products having a ready market in the European industrial countries, it is not to be wondered that, from a manufacturing point of view, the country should be still backward. Thus it is that, notwithstanding the fact that it produces the best cotton and wool in existence, it imports yearly for the value of about \$3,000,000 of cotton goods and \$2,000,000 of woolen goods; while the exports of the raw materials amount to about \$2,800,000 for cotton and \$3,500,000 for wool. These exports can be greatly increased; and no doubt will be, according as the country progresses.

If the irrigation schemes are carried into effect, the coast valleys will soon produce a tenfold of what they do now; and as the quality of the Peruvian staples is reputed among the best in existence, ready markets would always be found for the greater production.

With respect to the Peruvian wool-bearing animals, I have only to say that their wool is of such a very superior quality that it commands the highest prices in the market; unfortunately, this high price has caused as yet a limited demand, but I have every reason to believe that if the raising of these animals was to be carried on in the same economical and practical manner to be met with in the Australian sheep runs, the same success which this industry has obtained there would be obtained in Peru.

The textile industries of Peru are yet in their infancy. At present there is a manufactory of woolen goods in Lucre, in the Department of Cuzco. This manufactory dates since 1864, and has given a very large fortune to the owners, Messrs. Garmendia & Company, natives of Cuzco. Their idea was to manufacture the coarse woolen materials used by the native Indians of Peru and Bolivia, and also to supply the materials for the uniforms of the armies of both countries. This they have fully obtained, and there is an ever-increasing demand for their goods, both in the south of Peru as well as in the Bolivian markets.

As the estate of Lucre is situated in one of the best and most thickly populated districts of Cuzco, and where the best qualities of wool-bearing animals abound, the goods manufactured there are far superior to any similar European goods, owing to the fact that at Lucre only the pick of the wools is used, and such as is not exported to Europe. During the year 1890, Messrs. Prado, Hnos. and Pena established a wool manufactory at Lima, which, since then, has given every satisfaction, both to that firm and the general public. The machinery was built by the Societe Anonyme Vervetoise, and is quite modern—"self-acting" spinning machines, and other smaller machines, are of English make.

The Vitarte Cotton Mill, situated seven miles distant from Lima, in a cotton-growing district, was formerly the property of a Peruvian gentleman, who sold it last year to an English company—the "Peruvian Cotton Manufacturing Company, Limited." The original fitting consisted of 65 looms, producing 1,000,000 yards of cotton cloth per annum; and, since the English company took over the property, and invested large sums in fitting up 103 new looms, and erecting the latest and most improved modern machinery, the output has risen to 2,500,000 yards per annum of cotton cloth, besides great quantities of cotton wicking, waste, duck, towels, table cloths, etc. This mill is to-day as well equipped, and is as complete a concern as the best mill of a similar kind in this country. The demand for the Vitarte goods has always been in excess of the supply. The entire production is disposed of in Lima to local buyers as fast as it is turned out. Owing, as I have already pointed out, to the superior quality of the Peruvian staple, the goods manufactured at Vitarte are better and more adaptable to the native requirements; and thus it is that they always maintain their briskness, and that their demand is ever on the increase, notwithstanding the fluctuations of the market with respect to the imported article, which has to pay a comparatively heavy import duty of between 8 and 24 centavos per kilogramme.

The valleys of Ferrenafe, Chicama, Guadalupe, Santa, Supe, Canete, and the Lima district are, perhaps, among the most famous for the cultivation and production of the cane. In these valleys the estates are simply superb, and the greater part of them are fitted up with machinery of the latest and most modern type. The sugar industry in Peru has suffered to a very large extent, owing to the keen competition of beet sugar in the European markets and the increased production of cane in other countries, which has caused a considerable fall in prices. Then, again, the Peruvian producers have had to contend with scarcity of labor, limited water supplies, a long and protracted foreign war, which brought about a most serious financial crisis, the effects of which are felt even to-day.

Notwithstanding these drawbacks, the sugar industry is still one of the most important in the country, and one which promises to increase if proper attention is paid it. As a proof of this, I may mention that the production, during 1891, has reached 67,000 tons, an increase of about 10,000 tons over the preceding year. Some of the estates are provided with every modern appliance, such as narrow-gauge railways for the carriage of the cane from the fields to the sugar houses. During the last year an English company has bought over one of the estates in the Chicama Valley, and put up powerful machinery of the most modern description, of the well-known firm of Fawcett, Preston & Co. The sugar houses and the different departments have been fitted up with electric light, so that work is now going on at full pressure day and night. Due to the impulse which the capital invested has given to this estate, there is every reason to believe that this year's output of sugar alone will exceed 6,000 tons. The success which this venture has obtained, I understand, has been the cause of some inquiry after the Peruvian sugar estates, and I should not be at all surprised to learn that several others are being bought over by English companies.

Another instance where the purchase of a going concern in Peru has proved profitable to investors is the case of Messrs. Backus & Johnston's brewery in Lima. These gentlemen established, in 1880, a very large brewery in Lima, in order to meet the ever-increasing demand for a light lager beer. In 1890 their concern, which was at the time a most prosperous business, was bought over by an English company, and as a result of the capital invested in the business, I may mention that to-day the production has been quadrupled, and that the supply quite equals the demand.

The foregoing will convey to you what can be done in such a country as Peru when capital is forthcoming.

Like these, there are other industries which might be taken up and developed, and also others, entirely new to the country, which might be introduced at a great profit to the investors.

In the mining industries Peru has likewise had to depend upon native capital, and although we can boast of several big fortunes made in the mines, and within the last twenty years, I must confess that, in a great measure, this industry has not returned to its former prosperity, due to the scarcity of available capital in the country for the proper development of such an expensive and speculative industry.

Within the last few years some English companies have taken over Peruvian mines, and I have not heard of the investors having had any reason for complaint.

Speaking of the mining industries, I may mention the concentrating and smelting works at Casapalca, in the rich mining district of Huarochiri. These works date since 1889, and their products consist of base bullion and copper *matte*.

The plant is most perfect and consists of Freue-Venner concentrators, stamps, crushing mills, reverberatory furnaces, Bruckner furnaces, kilns, a 40 ton water jacket furnace. A complete laboratory is attached to the establishment, and in every respect the work ranks among the first of its class in South America. Sixty tons of ore can be treated daily at the works.

In the other mining districts I think that establishments of this class would be paying concerns, and although there are other smelting and concentrating works in Peru, yet none are so perfect as those at Casapalca.

One of the drawbacks in Peru to all industries has been the high price of fuel. English and Australian coal costs about £3 a ton in Lima, while the price for Chilean and native coal varies between 30s. and 40s. the ton. But, as I said before, that Peru might really be considered as nature's most favored country, the discovery of vast petroleum fields in different parts of the country, and the application of the crude oil as fuel in lieu of coal, has completely altered such a state of affairs.

The existence of bitumen, pitch, and petroleum in Peru was proved many years ago, but as always happens in the case of rich countries, while Peru had guano and nitrate to live upon, nobody worried himself about gold, silver, or oil. To-day things have changed, and so it is that every one now looks for the natural and true sources of wealth, such as agriculture and the many known rich mines which exist all over the immense territory. Following on this it was only natural that the petroleum district of Peru should have been surveyed, and the result has been to prove that Peru, in the department of Piura alone, possesses over 16,000 square miles of petroliferous soil. Such a discovery at a moment when coal keeps rising in price, and when petroleum is in greater and increasing demand, and is considered on all sides to be the destined fuel of the future, brought about something like a fever in the country, and a rush was made for the petroleum fields. In 1888, there were 23 claims registered; in 1889, 36; and in 1890, 97; and last year the number had risen to 613.

Since these discoveries, two English companies and two syndicates have already been formed in order to buy some of these properties. So at present these fields are being worked to some extent. The result has been that Peru will shortly consume entirely her own product, and that she will be in a condition to supply the whole South American markets, as well as China and Australasia.

The pioneer works in Peru belong to an Italian gentleman, Signor Piaggio, who has at Zorritos 54 claims of 40,000 square meters each. At present eleven wells are being worked, and these supply sufficient oil for refining 6,000 cases per month. These works have fine machinery, and the property is well equipped and fitted up in every respect.

Of the English companies, the London and Pacific Petroleum Company, Limited, is for the present the one which has the first and largest establishment for refining petroleum and supplying oil fuel in the country. The company possesses some tank steamers, and has just started an experiment of introducing Peruvian kerosene into China, a venture which I hope may meet with every success. The following figures will give an idea of the progress which this industry is already making at Zorritos:

EXPORTS.

(1888.)

	Kilos.
Crude oil	2,151,874
Kerosene	999,656
Lubricating clear oil	457,799

(1890.)

Crude oil	2,324,219
Kerosene	1,199,161
Lubricating clear oil	1,115,677

And from Talara, where the London and Pacific Petroleum Company are established, the exports during 1890

consisted of 1,100 tons of crude oil in tanks, 46,589 cases of kerosene, and 4,000 barrels of lubricating fine oil.

The future of mineral oil, as a fuel, has advanced another step, perhaps its final one, since the recent important invention of Mr. Chenhall for solidifying the crude oil. If, as appears from the tests and experiments to which the petroleum in its new form has been subjected by some of your most trustworthy and experienced engineers and chemical analysts, the problem of solidification has been solved, then indeed must Peru be congratulated on her extraordinary good luck, which will give the country a most valuable industry, one which I may describe as the parent industry to nearly all others. With fuel of a superior quality, advantageously situated for exportation, capital will not then tarry to come to the country, and give impulse and life to new and at present latent industries. What strides in the way of progress a country thus favored will be able to make, I leave to you to consider.

I must now bring my reading to an end, leaving many and important subjects for other and better hands than mine. But, before I sit down, I beg to call your attention to one point, which I am sure will interest you, even if commerce and industrial enterprise be not among the pursuits or callings of all. I refer to the action of the government of the United States of America, in promoting the establishment of a bureau of information of the Latin-American republics at Washington; and, I ask, why could not a similar thing be attempted here in this great metropolis, where undoubtedly the commercial, industrial, and financial interests of those countries are rooted, and from whence the capital, which gives life and vigor to every enterprise, emanates?

Some time ago a friend of mine, Mr. L. Tamini, an Argentine gentleman, communicated to me a plan for establishing in the great city of London a Latin-American Chamber of Commerce and Bureau of Information. I indorsed his views, and, with the help of Messrs. Baille, consul for Paraguay, and Mr. Mackinnon, consul for Uruguay, we tried to give form to this splendid idea. The financial crisis of 1890, and the political and economical outlook in some of the most important sections of the South American continent, spoiled our labors, which, perhaps, did not meet with all the encouragement which they deserved from the public supposed to be interested in Latin-American affairs. This, I believe, in sympathy to the abnormal situation which the city experienced at the time. However, be the reason and cause what it may, the fact is that we have not been able to carry out our idea on the lines proposed, and therefore have had to content ourselves—at least, for the time being—with an embryo chamber of commerce. This exists, perhaps, more in our imagination than in reality, but it nevertheless exists, and I think that, by a little propping here and raising there, it might be made the very bureau which I consider most important should exist in such a center as London.

The average Latin-American, who comes to this country on business, finds himself lost in London, as he ignores the language, and, above all, the special manner in which English business and transactions are conducted. If he does not fall into the clutches of men of straw, he may consider himself very lucky, but the chances are ten to one that, wishing to avoid them, he gets caught in their meshes at some boarding house where he is probably staying, in order to learn or practice, as the case may be, English. The result is that his business is hawked about, and as the person in charge of it is of very dubious standing, to put it mildly, it is naturally rejected, without the honors of a listening or of a reading. Meanwhile the confiding, but ignorant, would-be vendor is whiling away his time sight-seeing, and speculating on, when not actually living upon, his future gains. The months pass, and at last he is told that the times are bad; that money is tight or loose; that the state of his or of the neighboring country is troubled; that the smash of such a firm in Honolulu, or any other place on the earth, has produced a financial crisis, and that there is no prospect whatever of doing business for the moment. After having spent more money than was necessary, the individual returns home to tell his friends and countrymen that there is no business possible in England; and thus, perhaps, a good concession or a good business is thrown over or buried in oblivion until another chance is given it.

The bureau which I recommend would be the rendezvous for all Latin-Americans in this city. Thither they would go to discuss business and to meet the persons they should have made appointments with. As for the English portion of the public, they would be able to obtain from such a bureau all the information they should require without having to call upon the consuls at all hours, and get, perhaps, about one-tenth of what they expected.

That the proper organization of such a chamber or bureau is useful, need not be pointed out to you, as it is to-day a universally acknowledged fact that it is through such institutions, and by their aid, that the spreading of commerce is carried on.

I must now apologize to you all for my very dry discourse, which I thank you for having listened so attentively to. I hope that I have impressed you with the importance of the country which I have so poorly and confusedly attempted to describe to you, and that it and you may derive some positive benefit from what has been put forward.

Sir Alfred Dent thought the facts collected by Senor Pezet must carry a great deal of weight, seeing the important position he occupied in England as consul general for Peru. So long as Senor Pezet held that office, he felt confident that his country would be well served, and that those who came in contact with him would be well pleased. Among other subjects alluded to, was the interest which Englishmen had in Peru. That was perhaps more centralized now that a great company had been started in London, whose special business it was to work and develop all the railways and other properties which Peru had handed over to the bondholders, and to bring that enterprise into a good commercial position which would do credit to the Englishmen who undertook the work, and bring that success to Peru which the country so much needed. The railways were peculiarly interesting to those who had time to study them, seeing that many hundred thousands of pounds sterling had been spent upon them. The Southern Railway crossed the Andes at a great elevation, when it went down to Lake Titicaca, which was some 13,000 feet above the level of the sea, 150 miles long and 40 miles wide in many parts. The lake was navigated by two small steamers, and a third steamer of much larger capacity, which had recently been built upon the Clyde, would shortly be added. This steamer, which is 170 feet long, will shortly be shipped to Mollendo, and having been taken over the Andes and through the tunnels, would be put together on the border of the lake at Puno. It is proposed, by means of this steamer, to navigate the lake to the mouth of the river Desaquedero at the further end, in order to open the mineral districts; and in time the southern railway would probably be extended from that point to La Paz, the capital of Bolivia, thus increasing the lake traffic. The Central Railway, further north, commences at Callao and Lima, crosses the Cordilleras at an elevation much higher than Mont Blanc. It afterward dives down in the direction of the tributaries of the Amazon into a fertile agricultural country, and it is the forests of this country that the well known Ceylon planters Mr. Ross, Mr. Sinclair and Mr. Clarke have been exploring lately on behalf of the Peruvian Corporation. They all give a glowing description of the soil and district from a planter's point of view; and it is hoped that several planting industries will soon be started there under the management of Ceylon men. The two difficulties to be dealt with are those of labor and transport, though the latter would be overcome, no doubt, as soon as the railways were extended. With regard to the labor, they were told there were a good many natives in the interior of Peru, but it was a question how far that labor was available to meet the wishes and wants of English planters. They hoped to introduce foreign labor—Chinese and others—and they looked to the Peruvian authorities to do all they could to assist them in this direction. The Chinese were a very industrious class, and if properly treated, prove to be the best laborers in the world for the tropical regions. As regarded petroleum, which was being extracted by one or two companies, he might say that petroleum was being largely used in the form of liquid fuel on the railways, nearly all the locomotives having been converted so that they could burn refuse petroleum, thus effecting a saving of some 40 or 50 per cent. They had been told that English coal cost £3 a ton in Lima, but he was glad to say they could get it for considerably less than that now, though in many of the mining districts the miners would willingly pay £12 a ton for coal. Speaking from an agricultural point of view, from all accounts to hand it was clear that the soil was of a very rich kind, and the climate also was most enviable. At Lima the temperature was from 60° to 80°, which was the most perfect climate to live in. Fevers were comparatively unknown there. Peru had one advantage over many of the South American states, viz., that its paper currency had practically disappeared, wages and the like being paid in coin (Peruvian dollars). Senor Pezet had rather led the meeting to believe that the question of solidifying petroleum had been solved, but perhaps the Society of Arts would have a word to say upon that question later on, as many seemed to doubt whether this question had been absolutely settled. No doubt if the refuse petroleum could be solidified, when it might be easily carried, and afterward liquefied so as to be used on board ship, it would do a great deal toward supplanting coal. He was strongly in favor of the establishment of a bureau in this country at which information could be obtained by those who wished to seek their fortunes in South American colonies. The first qualification necessary for that was a knowledge of the Spanish language. It had been the fashion of late years to learn German, though he could not quite see the use of this language to a man who had to make his way in the world. It might be useful for academic purposes, but it was not nearly as useful a language as Spanish in the colonies of the New World. Of course, this was a subject upon which opinions might differ.

THE CHEMICAL WORKS OF FARADAY IN RELATION TO MODERN SCIENCE.*

By Prof. DEWAR, M.A., F.R.S.

PROF. DEWAR commenced his lecture by saying that his eminent colleague had done such ample justice to the physical side of Faraday's work that his own task would be limited to dealing with those early researches in which he developed that astounding manipulative power which enabled him to conduct his subsequent electrical investigations in so remarkable a manner. He proposed to give a brief sketch of the more important of the distinctive chemical labors of Faraday, and then to select one of the many veins of investigation he had opened up, and show what had resulted from its development.

Faraday's chemical work might be divided into the following groups or periods: Period of Analytic Work. Organic Research. Study of Gaseous Properties. Investigations on Steel and Glass. Determination of Electro-chemical Equivalents. Regelation. Action of Metals on Light. Work on Chemical Manipulation. Published Lectures.

Having given a short *resume* of Faraday's progress through these subjects, Prof. Dewar referred to his first great work in organic research, the production of two compounds of chlorine and carbon, the perchloride and the protochloride, and the determination of the composition of "Julian's chloride of carbon." The original specimens prepared by Faraday were exhibited, and it was pointed out that the discoverer's analyses of these bodies were absolutely accurate, notwithstanding the difficulties attending such work at that time. His discovery of "bicarburet of hydrogen" (now widely known and largely manufactured as benzol) and a "new hydrocarbon" (now known as butylene) was then described, it being pointed out that having regard to the methods of working which Faraday had to employ, the isolation and determination of the composition of such bodies was marvelous, and was to be explained only by his wonderful manipulative skill.

Probably Faraday's most remarkable discovery in organic chemistry was the fact that naphthalene could be dissolved by strong sulphuric acid, and that when thus dissolved the solution did not precipitate naphthalene on being treated with water. That enabled him to prove combination between sulphuric acid and a hydrocarbon. The body, which he called "sulpho-naphthalic acid," is probably the first of the sulpho-acids now so largely employed in the color industry.

Faraday's next important work was an investigation into the properties of combinations of steel with other metals, in the course of which he demonstrated the now well recognized fact that an admixture of such minute proportions as $\frac{1}{500}$ of such metals as silver, nickel, palladium, etc., will entirely alter the character of the metal. Concurrently with this, he worked on the improvement of optical glass, and it was observed that although the fruits of his labors in this direction lay dormant for some time, they ultimately resulted in one of his most important discoveries, namely, the rotation of the plane of polarization in the magnetic field. The glass produced by Faraday by the fusion of oxide of lead with boracic acid was selected by him, because of its superior fluidity, combined with great density. (Experiments were given illustrating the peculiar physical and electrical properties of the Faraday glass.)

The next research was that on the liquefaction of gases, which, although carried out by Faraday, was nevertheless done at the instigation of Davy. Davy had discovered a substance which proved to be a hydrate of chlorine, and which he found could be kept either in ice or in sealed tubes. Faraday had produced a quantity of this substance during the cold weather, and had made an analysis of it. Davy then suggested that it should be heated in a sealed tube, and, without saying what he really expected to take place, indicated that one of three things would happen, namely, that it would either melt, act on water, or produce liquid chlorine. The latter event happened, and opened up vast possibilities, the prosecution of which Davy left to Faraday. (Experiment on the liquefaction of chlorine given.) The necessity of obtaining tubes strong enough to stand the pressure required for the liquefaction experiments led Faraday to make investigations at this time into the production of bottle and other glass.

Faraday next turned his attention to researches on the electro-chemical relations of bodies, crystallization, and the action of metals on light. It was in connection with the research on crystallization in 1856 that Faraday made his interesting discovery of the phenomenon of regelation, by virtue of which two portions of a piece of ice, after being severed, freeze together again on being brought into contact, even when the temperature of the surrounding medium is higher than the freezing point of water. Although discovered by Faraday, it was not until comparatively recent times that the explanation of the phenomenon was given and its influence on glacial motion clearly established. (Experiment on regelation shown.)

Specimens, arranged and tabulated by himself, of Faraday's last research on the optical properties of gold leaf in a highly attenuated form were exhibited and described.

Turning then to the special subject of the evening's discourse, the liquefaction of gases, Prof. Dewar stated that, although Faraday made his first researches in this direction as early as 1823, the matter lay dormant for many years, until his interest in it was reawakened by Thilorier's discovery that solid carbonic acid could be produced in the form of a snow-like substance, boiling at −80° C., and capable of being handled. Faraday was the first to introduce this discovery into England in a lecture given at the Royal Institution on the 18th May, 1838, and thereafter by its aid he resumed his work on the liquefaction of the various gases which had resisted his former efforts. All through the summer of 1844 he was busily employed at this work, using the low temperatures which Thilorier's new product enabled him to obtain, combined with great pressures. (Specimens of gases thus liquefied by Faraday shown.) This important work was the subject of a Friday evening lecture given at the Royal Institution early in 1845, a full abstract of which appeared in the *Times* of that date, the Institution itself not having then commenced the publication of its proceedings. In the course of that address Faraday produced a small quantity of ethylene, and he expressed the opinion that if a method could be found of producing liquid nitrous oxide in large quantities, that would be the material which would enable him to liquefy oxygen and the other gases which had hitherto resisted all his efforts. (Experiments showing the comparative boiling points of solid carbonic acid, nitrous oxide, and ethylene at ordinary pressure and under diminished pressure given.) Faraday hoped that the production of solid nitrous oxide would enable him to get temperatures as far below the boiling point of carbonic acid as the temperature of that body was below ordinary temperatures. As a matter of fact, it is impossible to reach such low temperatures by the agency of solid nitrous oxide, and such great depression of temperature was not attained until such time as liquid ethylene became available. The lecturer here showed and described a diagram of the machinery and apparatus now employed at the Royal Institution for the liquefaction and solidification of gases. The method of producing liquid ethylene and of employing it over and over again in the apparatus was described.

The work done in connection with this subject since the time of Faraday, and especially the investigations of Andrews and Van der Waals, had enabled scientists of the present day to calculate exactly the temperature of the boiling point of hydrogen, the gaseous body which has in the liquid state the lowest boiling point of all the elementary substances, and which has up to the present time resisted liquefaction. The temperature of boiling hydrogen would be −250° C. The lowest point attained by Faraday was −110° C., and the lowest temperature yet reached was −210° C.

Prof. Dewar then performed the experiment of actually producing liquid oxygen, which was seen to boil quietly when collected in an open vessel at a temperature of −180° C. The color was slightly blue, only a few particles of solid matter being visible, which Prof. Dewar explained were traces of solid carbonic acid, the elimination of which had given him considerable trouble. The lecturer further proved by actual experiment on his own hand and on a glass vessel that the liquid oxygen was in the spheroidal

* An address delivered at the Faraday Centenary, Royal Institution of Great Britain, Friday, June 26, 1891.

condition; and also that alcohol when added to the liquid became instantly solidified. The usual test for oxygen by means of a glowing taper was also made on the vapor given off by the liquid.

Prof. Dewar stated that the prosecution of the researches inaugurated by Faraday was enabling scientists to approach nearer and nearer to the zero of absolute temperature; and the speculations of physicists were now directed to the probable characteristics of hydrogen and of matter in general when that condition should be attained. At such a temperature the properties of matter would in all probability be entirely changed; the old Lucretian law would be suspended, molecular motion would probably cease, and what might be called the death of matter would ensue, as in fact the death of chemical affinity and chemical action was known to take place at the low temperatures already attainable. (Experiment proving this by the immersion of phosphorus, sodium, and potassium in liquid oxygen.) On the other hand, it was found that even at such low temperatures oxygen retained its characteristic absorption spectrum.* Further experiments were given proving the liquefaction of ozone by means of liquid oxygen—a tube of the liquid thus produced showing the characteristic deep blue color of that substance.

In conclusion, Prof. Dewar said that although great progress had been made since Faraday's time, chemists were still working distinctly on the lines of his early researches, and it seemed to him that no fitter method of celebrating the centenary of Faraday's birth could be chosen than the demonstration of the realization of some of his own ideas.

On the conclusion of the lecture, a vote of thanks to Prof. Dewar was moved by the Lord Chancellor, who said:

My Lord Duke, my Lords, Ladies, and Gentlemen: I am very happy indeed to be made the instrument of conveying your thanks for the most interesting lecture we have listened to. I could not help thinking while our lecturer was giving us an account of all these wonderful things, that he was illustrating in his own person something which he had said. He pointed out how the torch of science was passed on from hand to hand; how, for instance, Davy had handed to Faraday some of the sources of those great discoveries which he afterward disclosed to the world; and I thought that it required some such successor to give adequate expression to the history of Faraday's work. Faraday had many friends; many of us have listened to him in this theater, as, indeed, I have had the privilege of doing myself; and I think I may say that no one came within the sphere of his kindly and gentle influence who did not become a hearty and attached friend. But I should think that very few of those friends would be able to give adequate expression to what he had done, the discoveries he had made, and the ever-increasing effect which those discoveries had exercised upon the progress of modern science. We have listened to-night to a most able exposition of Faraday's work, and I think that Prof. Dewar has shown that he has in truth succeeded to that work, that he is worthy to receive that torch, and carry it on and give a brighter illumination to science than it has ever yet received. I am sure that there is none here who will not heartily join with your grace in thanking Prof. Dewar for the able, learned, and lucid lecture in which he has explained to ignorant people like myself Faraday's wonderful discoveries in science.

Sir Lyon Playfair, in seconding the motion, said: It is indeed a great privilege to all of us to see the great progress which has been made in the discoveries of Faraday during the last fifty years. Those little tubes containing the original liquefied gases which Faraday liquefied under pressure and low temperatures were very important, and were considered at the time very remarkable productions. But you see how the subject has since grown; how carbonic acid, for instance, first liquefied, has since been solidified so that it can be handled like snow; and you have seen the remarkable way in which oxygen has been liquefied on the present occasion. An old professor of chemistry like myself can appreciate the wonderful manipulative power which Prof. Dewar has displayed this evening. Even in the chemical laboratory, with everything quiet around you, it is difficult to make these experiments successfully, but in a theater of this kind it is marvelous how everything goes wrong; and if we had not had a manipulator of great accuracy and knowledge, we could not have had the gratification which we have enjoyed this evening. What strikes me as being so excellent in my friend, and much more than friend—for he is the greatest chemist that I ever produced, and I am extremely glad to think that he looks up to his old teacher with affection while I look to him with love and honor—what I wanted to say is, that I think he has done quite rightly in giving you the scientific side of these wonderful discoveries, and showing you the way in which they are growing and giving us a better knowledge of the condition of matter. When Faraday first made experiments like these, some wiseacres said, "What is the use of it?" Faraday replied, "Will you tell me what is the use of a baby?" But Faraday's baby has centered around it all the hopes and desires of the parents that produced it, and the state also has shown much interest in its upbringing. The bodies that appear in those tubes have become important factors in the progress and industry of the world. The carbonic acid, which I recollect first seeing as a little globule of acid, is now carried in cylinders filling railway trucks, and is applied to many purposes, some important, others more useful than important. For instance, the liquid carbonic acid enables barmaids to get beer up from the cellars below without pumping it; that nitrous oxide which we were so interested in as a condensed gas is now largely used by dentists as a means of extracting our teeth without pain; sulphurous acid will, I am certain, become most important in war, for if you took a brittle shell filled with liquid sulphurous acid and threw it between the decks of a ship it would produce such a stink that everybody would disappear in a moment. The time is coming when other gases will be used in this way. Their importance does not altogether consist in their applications to industry, though they are becoming very important in that way. But their importance is that they are teaching us more of the constitution and properties of matter; it is in that respect that they are becoming so interesting in the eyes of scientific men. I have been extremely interested in watching the production of that liquid oxygen. I looked upon it with great respect and wondered to see it not covered with a cage as if likely to go off at any moment in a terrific explosion. But it is produced in such a manner that its own cold keeps it down, and so we saw it handled in the most marvelous way as an ordinary liquid. I have the utmost pleasure in seconding the vote of thanks to Prof. Dewar for the brilliant exposition which he has given to us.

* The recently discovered magnetic property of the liquid adds a new interest to this substance.

"Royal Institution, 10th December, 1891.

"DEAR SIR WILLIAM THOMSON: The following observation, which I have just made, may interest the members of the Royal Society, and if you think it of sufficient importance you may announce it at this day's meeting.

"At 3 P. M. this afternoon I placed a quantity of liquid oxygen in the state of rapid ebullition in air (and therefore at a temperature of −181° C.) between the poles of the historic Faraday magnet, in a cup-shaped piece of rock salt (which I have found is not moistened by liquid oxygen, and therefore keeps it in the spheroidal state), and to my surprise I have witnessed the liquid oxygen, as soon as the magnet was stimulated, *suddenly leap up the poles and remain there permanently attached until it evaporated.* To see liquid oxygen suddenly attracted by the magnet is a very beautiful confirmation of our knowledge of the properties of gaseous oxygen. Yours faithfully, JAMES DEWAR."—*Proc. Roy. Soc.*, vol. l., p. 24.

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